Final Report

BART Analysis for Apache Generating Station Steam Unit 3

Prepared for

AEPCO

Prepared by

CH2MHILL

December 2007

175887

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Steam Unit 3

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Executive Summary

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Background

In response to the Regional Haze Rule and Best Available Retrofit Technology (BART) regulations and guidelines, Arizona Electric Power Cooperative (AEPCO) requested that CH2M HILL perform a BART analysis for Apache Unit 3 (hereafter referred to as ST3). AEPCO's Apache Generating Station facilities include seven electric generating units, two of which are 195-megawatt (MW) natural gas- and coal-fired steam electric generating units. ST3 is one of these two units. The BART analysis for ST3 addressed the following criteria pollutants: oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and particulate matter less than 10 micrometers in aerodynamic diameter (PM_{10}). BART emissions limits must be achieved within 5 years after the State Implementation Plan (SIP) is approved by the United States Environmental Protection Agency (EPA). A compliance date of 2013 was assumed for this analysis.

In completing the BART analysis, technology alternatives were investigated and potential reductions in NO_x, SO_2, and PM_{10} emissions rates were identified. The following technology alternatives were investigated, listed below by pollutant:

- NO_x emission controls:
  - New/modified state-of-the-art low-NO_x burners (LNB) with advanced over-fire air (OFA)
  - Rotating Opposed Fire Air (ROFA)
  - Selective non-catalytic reduction system (Rotamix and SNCR)
  - Selective catalytic reduction (SCR) system
  - Neural Network Controls (Neural Net)
- SO_2 emission controls:
  - Enhancements to the existing wet limestone scrubber, also called the Sulfur Dioxide Absorption System (SDAS)
- PM_{10} emission controls:
  - Performance upgrades to existing hot-side electrostatic precipitator (ESP)
  -
  - Replace current ESP with fabric filter unit
  - Polishing fabric filter after ESP

BART Engineering Analysis

The specific components of a BART engineering analysis are identified in the *Code of Federal Regulations* (CFR) at 40 CFR 51 Appendix Y, Section IV. The evaluation must include:

1. The identification of available, technically feasible, retrofit control options
2. Consideration of any pollution control equipment in use at the source (which affects the availability of options and their impacts)
3. The costs of compliance with the control options
4. The remaining useful life of the facility
5. The energy and non-air quality environmental impacts of compliance
6. The degree of visibility improvement that may reasonably be anticipated from the use of BART

These components are incorporated into the BART analysis performed by CH2M HILL through the following steps:

- **Step 1—Identify all available retrofit control technologies**
- **Step 2—Eliminate technically infeasible options**
  - The identification of available, technically feasible, retrofit control options
  - Consideration of any pollution control equipment in use at the source (which affects the applicability of options and their impacts)
- **Step 3—Evaluate control effectiveness of remaining control technologies**
- **Step 4—Evaluate impacts and document the results**
  - The costs of compliance with the control options
  - The remaining useful life of the facility
  - The energy and non-air quality environmental impacts of compliance
- **Step 5—Evaluate visibility impacts**
  - The degree of visibility improvement that may reasonably be anticipated from the use of BART

Separate analyses have been conducted for NO_x, SO_2, and PM_{10} emissions. All costs included in the BART analyses are in 2007 dollars, and costs have not been escalated to the assumed 2013 BART implementation date.

Coal Characteristics

Sources of coal burned at ST3 are anticipated to be from the northern Colorado, Wyoming's Powder River Basin (PRB), and the Four Corners region of New Mexico. As detailed below in Table 2-2, the Colowyo, Twentymile, Elk, and West Elk mines are located in northern Colorado. Jacob's Ranch, Bowie #2, Black Thunder, Antelope, and North Antelope Rochelle Mines are all located in the PRB. The Lee Ranch mine is in the Four Corners region of New Mexico. Some of these coals are ranked as bituminous and some are sub-bituminous, which influences the level of NO_x emissions from the boiler. The bituminous coals have higher nitrogen content than sub-bituminous coals such as those from the PRB, which represent the bulk of sub-bituminous coal use in the U.S. This BART analysis has considered the higher nitrogen content and different combustion characteristics of bituminous versus sub-bituminous coals planned to be burned at ST3, and has evaluated the effect of these qualities on NO_x formation and achievable emission rates.

Recommendations

NO_x Emission Control

Based on the results of this analyses, the replacement of the existing burners with new LNBs with OFA are recommended as BART for ST3, based on the projected significant reduction in NO_x emissions, reasonable control costs, and the advantages of no additional power requirements or non-air quality environmental impacts.

SO_2 Emission Control

Based on the results of this analysis, upgrading the existing limestone scrubber system is recommended as BART for ST3. This is based on the potential of additional reduction in SO_2 emissions, reasonable control costs, and the advantages of minimal additional power requirements and non-air quality environmental impacts.

PM_{10} Emission Control

Based on the results of this analysis, precipitator upgrades are recommended as BART for PM_{10} emission control. This is based on the potential of additional reduction in PM_{10} emissions, reasonable control costs when compared to the control technology alternatives analyzed, and the advantage of no non-air quality environmental impacts.

BART Modeling Analysis

CH2M HILL used the CALPUFF modeling system to assess the visibility impacts of emissions from ST3 at Class I areas. The Class I areas potentially affected are located more than 50 kilometers, but less than 300 kilometers, from the Apache Generating Station. The Pine Mountain WA Area (WA) has been included in the analysis because it is located just outside of the 300-kilometer radius from the Apache Plant.

The Class I areas include the following:

- Chiricahua National Monument (NM)
- Galiuro WA
- Gila WA
- Superstition WA
- Mount Baldy WA
- Pine Mountain WA

- Sierra Ancha WA
- Mazatzal WA
- Saguaro National Park (NP)

Although ST3 will simultaneously control NO_x, SO_2, and PM_{10} emissions, seven post-control atmospheric dispersion modeling scenarios were developed to cover the range of effectiveness for independent NO_x and PM_{10} control technologies. Because only one control scenario for SO_2 is included in this analysis (scrubber upgrades), it was determined that modeling was not necessary for this pollutant.

The modeling scenarios, and the controls assumed, are as follows:

- Scenario 1: New LNB with OFA modifications
- Scenario 2: ROFA
- Scenario 3: ROFA with Rotamix
- Scenario 4: New LNB with OFA modifications and SNCR
- Scenario 5: New LNB with OFA modifications and SCR
- Scenario 6: Polishing COHPAC fabric filter
- Scenario 7: Fabric filter

Visibility improvements for all emission control scenarios were analyzed, and the results were compared using a least-cost envelope, as outlined in the draft *New Source Review Workshop Manual (EPA 1990).*

Least-cost Envelope Analysis

The EPA has adopted the Least-cost Envelope Analysis Methodology as an accepted methodology for selecting the most reasonable, cost-effective controls. Incremental cost-effectiveness comparisons focus on annualized cost and emission reduction differences between dominant alternatives. The dominant set of control alternatives is determined by generating what is called the envelope of least-cost alternatives. This is a graphical plot of total annualized costs for a total emissions reductions for all control alternatives identified in the BART analysis.

To evaluate the impacts of the modeled control scenarios on the eight Class I areas, the total annualized cost, cost per deciview (dV) reduction, and cost per reduction in number of days above 0.5 dV were analyzed. This report provides a comparison of the average incremental costs between relevant scenarios for the nine Class I areas; the total annualized cost versus number of days above 0.5 dV, and the total annualized cost versus 98th percentile delta-deciview (ΔdV) reduction.

Results of the Least-cost Envelope Analysis validate the selection the recommended controls for NO_x, SO_2 and PM_{10} based on incremental cost and visibility improvements.

Just-Noticeable Differences in Atmospheric Haze

Studies have been conducted that demonstrate only dV differences of approximately 1.5 to 2.0 dV or more are perceptible by the human eye. Deciview changes of less than 1.5 cannot be distinguished by the average person.

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Acronyms and Abbreviations

A/C	Air to Cloth
ADEQ	Arizona Department of Environmental Quality
AEPCO	Arizona Electric Power Cooperative
ASTM	American Society for Testing and Materials
BACT	Best Available Control Technology
BART	Best Available Retrofit Technology
Btu	British thermal units
CALDESK	Program to display data and results
CALMET	Meteorological data preprocessing program for CALPUFF
CALPOST	Post-processing program for calculating visibility impacts
CALPUFF	Puff dispersion model
CDPHE	Colorado Department of Health and Environment
CFR	*Code of Federal Regulations*
CO	carbon monoxide
COHPAC	Compact Hybrid Particulate Collector
dV	deciview
ΔdV	delta deciview, change in deciview
ESP	electrostatic precipitator
EPA	United States Environmental Protection Agency
Fuel NO_x	oxidation of fuel bound nitrogen
FLM	Federal Land Managers
f(RH)	relative humidity factors
kW	kilowatts
kW-Hr	kilowatt-hour
LCC	Lambert Conformal Conic
LAER	lowest achievable emission rate
lb/MMBtu	pounds per million British Thermal Units
LNB	low-NO_x burner
LOI	loss on ignition
$\mu g/m^3$	micrograms per cubic meters
MMBtu	Million British Thermal Units
MM5	Mesoscale Meteorological Model, Version 5

MW	megawatts
N_2	nitrogen
NM	National Monument
NO	nitric oxide
NO_x	oxides of nitrogen
NP	National Park
NWS	National Weather Service
OFA	over-fire air
$PM_{2.5}$	particulate matter less than 2.5 micrometers in aerodynamic diameter
PM_{10}	particulate matter less than 10 micrometers in aerodynamic diameter
PRB	Powder River Basin
ROFA	Rotating Opposed Fire Air
SCR	selective catalytic reduction system
SDAS	Sulfur Dioxide Absorption System
SIP	State Implementation Plan
SNCR	selective non-catalytic reduction system
SO_2	sulfur dioxide
SO_3	sulfur trioxide
Thermal NO_x	high temperature fixation of atmospheric nitrogen in combustion air
UFA	under-fire air
USGS	U.S. Geological Survey
WA	Wilderness Area
WRAP	Western Regional Air Partnership

Section 1.0
Introduction

1.0 Introduction

The Clean Air Act established goals for visibility improvement in national parks (NPs), wilderness areas (WAs), and international parks. Through the 1977 amendments to the Clean Air Act in Section 169A, Congress set a national goal for visibility as "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas, which impairment results from manmade air pollution." The Amendments required the United States Environmental Protection Agency (EPA) to issue regulations to assure "reasonable progress" toward meeting the national goal. In 1990, Congress again amended the Clean Air Act, providing additional emphasis on regional haze issues.

In 1999, the EPA issued comprehensive regulations to improve visibility, or visual air quality, in the 156 NPs and WAs across the country classified as mandatory Class I areas. These regulations include requirements for states to establish goals for improving visibility in NPs and WAs and to develop long-term strategies for reducing emissions of air pollutants that cause visibility impairment.

One of the principal elements of the visibility protection provisions of the Clean Air Act addresses installation of best available retrofit technology (BART) for certain existing sources placed into operation between 1962 and 1977. The 1999 Regional Haze Rule requires the following three basic state plan elements related to BART:

- A list of BART-eligible sources (includes sources of air pollutants that are reasonably anticipated to contribute to visibility impairment in a Class I area)
- An analysis of the emission reductions and changes in visibility that would result from "best retrofit" control levels on sources subject to BART
- The BART emission limits for each subject source, or an alternative measure, such as an emissions trading program for achieving greater reasonable progress in visibility protection than implementation of source-by-source BART controls

In determining BART, the state can take into account several factors, including the existing control technology in place at the source, the costs of compliance, energy and non-air environmental impacts of compliance, remaining useful life of the source, and the degree of visibility improvement that is reasonably anticipated from the use of such technology (EPA, 1999).

In July 2005, the EPA released specific BART guidelines for states to use when determining which facilities must install additional controls, and the type of controls that must be used. Under current regulatory deadlines, states—including Arizona—must submit a Regional Haze Rule State Implementation Plan (SIP) amendment that addresses BART implementation by December, 2007. In this plan amendment, states will identify the facilities that will have to reduce emissions under BART and then set BART emissions limits for those facilities, or identify any alternative plan for reducing visibility impairing pollutants that would achieve greater reductions than those realized from BART emissions limits (EPA, 2005).

Using information from the Western Regional Air Partnership (WRAP) and its Regional Modeling Center, the State of Arizona has identified those eligible in-state sources that are required to reduce emissions under BART, and has directed those sources to complete BART analyses to identify potential reductions for emissions of sulfur dioxide (SO_2), oxides of nitrogen (NO_x) and particulate matter less than 10 micrometers in aerodynamic diameter (PM_{10}) that would be associated with additional or new air pollution controls. This information will be included in the State's SIP that is due in December 2007. At this time, it is expected that Arizona's SIP will address reduction of SO_2 emissions at BART sources through an alternative measure in the form of a four-state backstop cap-and-trade program. Reduction of NO_x and PM_{10} emissions will be addressed through establishment of BART emissions limits in source operating permits.

The EPA BART guidelines state that the BART emission limits established as a result of BART analyses must be fully implemented within 5 years of the EPA's approval of the SIP. For the purposes of this project, that date is assumed to be 2013.

This report documents the BART analysis performed on Apache Steam Unit 3 (hereafter referred to as ST3) on behalf of Arizona Electric Power Cooperative (AEPCO) by CH2M HILL. The analysis was performed for the pollutants NO_x, SO_2, and PM_{10}.

Section 2.0 of this report provides a description of the present unit operation, including a discussion of coal sources and characteristics. The BART Engineering Analysis is provided in Section 3.0, by pollutant type. Section 4.0 provides the methodology and results of the BART Modeling Analysis, followed by recommendations in Section 5.0. References are provided in Section 6.0. Appended to this report is additional information related to the Economic Analysis performed to support the BART Engineering Analysis and BART protocol.

Section 2.0
Present Unit Operation

2.0 Present Unit Operation

The Apache Generating Station consists of seven electric generating units with a total generating capacity of 560 megawatts (MW). The power plant is located approximately 3 miles southeast of the town of Cochise in the Willcox Basin in Cochise County, Arizona. Apache Steam Unit 3 (hereafter referred to as ST3) is a 195-MW coal-fired steam electric generating unit equipped with a dry-bottom, turbo-fired coal boiler manufactured by Riley Stoker. The unit was constructed with a hot-side electrostatic precipitator (ESP) for particulate matter control and a wet limestone scrubber system, also referred to as a Sulfur Dioxide Absorption System (SDAS), for SO_2 control.

ST3 commenced construction in 1976 and was placed in service in 1979. This analysis is based on an approximate 20-year life for BART control technologies. Assuming a BART implementation date of 2013, this estimates the technologies will operate until 2033. This is close to the projected remaining useful life for ST3 of 22 years (until 2035) based on the unit's most recent engineering life assessment.

Table 2-1 lists additional unit information and study assumptions for this analysis.

TABLE 2-1
Unit Operation and Study Assumptions
ST3

General Plant Data	
Site Elevation (feet above mean sea level)	4,200
Stack Height (feet)	394
Stack Exit Internal Diameter (feet)/Exit Area (square feet)	16.58 /215.9
Stack Exit Temperature (°F) [b]	135
Stack Exit Velocity (feet/second) [b]	58.0
Stack Flow (standard cubic feet/hour) [c]	3.2 x 107
Annual Unit Capacity Factor (percentage)[1]	87.4
Net Unit Output (MW)	195
Net Unit Heat Rate (Btu/kW-Hr) (100 percent load)	10,336
Boiler Heat Input (MMBtu/hour)(100 percent load)	1,814 (as measured by CEM)
Type of Boiler	Dry-bottom turbo-fired
Boiler Fuel	Coal
Coal Sources	See Table 2-2
Current NO_x Controls	OFA/UFA
Average NO_x Emission Rate (lb/MMBtu) [d]	0.430
Current SO_2 Controls	Limestone-based wet scrubber
Average SO_2 Emission Rate (lb/MMBtu)[a]	0.151
Current PM_{10} Controls	ESP
PM_{10} Emission Rate (lb/MMBtu) [b]	0.007 to 0.045

NOTES:
[a] Average emissions from 2005 to 2007
[b] From test data 1997 to 2006
[c] CEM Calculation
[d] Average emissions from 2002 to 2007
[1] Capacity factor provided by AEPCO

For Table 2-1 above, emissions for the years 1997 to 2007 were analyzed to obtain the average ST3 NO_x emissions. The average SO_2 emissions were obtained from information from 2005 to 2007 because this timeframe is more representative of current ST3 operation.

In the July 2005 EPA BART guidelines, the EPA prescribed presumptive BART limits to be achieved at BART-eligible coal-fired power plants with a total generating capacity greater than 750 MW. Because the total generating capacity of the Apache Station is 600 MW, the presumptive limits do not apply. Therefore we will refer to the presumptive emissions limits only as a general point of reference and not as an emissions limit that must be achieved per prescribed EPA guidance.

The BART-presumptive NO_x limit for dry bottom turbo-fired boilers burning sub-bituminous coal is 0.23 pounds per million British thermal units (lb/MMBtu) and the BART presumptive NO_x limit for burning bituminous coal is 0.32 lb/MMBtu. Projected sources of coal to be burned at ST3 are summarized in Table 2-2.

TABLE 2-2
Coal Sources and Characteristics
ST3

					Ultimate Analysis (% dry basis)								
Mines	**Moist %**	**Ash %**	**Volatile Matter %**	**Fixed Carbon %**	**Btu/lb**	**Sulfur %**	**Carbon**	**Hydrogen**	**Nitrogen**	**Chlorine**	**Sulfur**	**Ash**	**Oxygen**
West Elk Mine, CO	7.50	9.50	35.60	47.40	12,120	0.58	66.70	4.60	1.42	0.01	0.58	9.50	9.70
Twentymile Mine, CO	9.40	9.80	35.80	45.00	11,400	0.50	70.70	5.00	1.80	0.01	0.55	10.80	11.14
Elk Creek Mine, CO	6.44	10.84	33.29	49.43	12,196	0.61	70.19	4.85	1.55	0.03	0.61	10.84	5.51
Colowyo Mine, CO	16.80	6.19	32.49	44.93	10,400	0.36	59.54	3.96	1.33	0.00	0.38	6.19	12.07
Bowie #2, CO	8.72	7.99	33.68	49.61	12,054	0.38	70.21	4.82	1.57	0.02	0.38	7.99	6.31
Antelope Mine, WY	26.70	5.25	31.70	36.11	8,800	0.24	51.35	3.59	0.78	0.01	0.24	5.25	12.08
Low Jacob's Ranch, WY	27.35	5.49	33.57	33.19	8,781	0.40	49.86	3.60	0.72	0.01	0.40	5.49	12.58
High Jacob's Ranch, WY	26.94	6.80	32.50	32.89	8,800	0.88	51.26	3.89	0.80	<0.01	0.88	6.80	9.44
Black Thunder Mine, WY	26.78	5.63	31.49	36.09	8,794	0.30	51.88	3.34	0.58	0.02	0.30	5.63	11.48
N. Ant/Rochelle, WY	27.40	4.40	31.10	37.10	8,800	0.20	70.90	4.80	0.90	<0.01	0.28	6.10	17.02
Lee Ranch Mine, NM	15.30	17.80	33.50	33.40	9,250	0.90	61.70	4.50	1.00	0.01	1.06	21.00	10.73

NOTE:
Data as per report done by AEPCO updated May 2007

Section 3.0
BART Engineering Analysis

3.0 BART Engineering Analysis

3.1 BART Process

The specific components in a BART engineering analysis are identified in the *Code of Federal Regulations* (CFR) at 40 CFR 51 Appendix Y, Section IV. The evaluation must include the following:

1. The identification of available, technically feasible, retrofit control options
2. Consideration of any pollution control equipment in use at the source (which affects the availability of options and their impacts)
3. The costs of compliance with the control options
4. The remaining useful life of the facility
5. The energy and non-air quality environmental impacts of compliance
6. The degree of visibility improvement that may reasonably be anticipated from the use of BART

These components are incorporated into the BART analysis performed by CH2M HILL through the following steps:

- **Step 1—Identify all available retrofit control technologies**
- **Step 2—Eliminate technically infeasible options**
  - The identification of available, technically feasible, retrofit control options
  - Consideration of any pollution control equipment in use at the source (which affects the applicability of options and their impacts)
- **Step 3—Evaluate control effectiveness of remaining control technologies**
- **Step 4—Evaluate impacts and document the results**
  - The costs of compliance with the control options
  - The remaining useful life of the facility
  - The energy and non-air quality environmental impacts of compliance
- **Step 5—Evaluate visibility impacts**
  - The degree of visibility improvement that may reasonably be anticipated from BART use

In the evaluation, consideration was made of any pollution control equipment in use at the source, the costs of compliance associated with the control options, and the energy and non-air quality environmental impacts of compliance using these existing control devices. As a consequence, controls scenarios included enhancement of existing equipment, as well as addition of new control equipment.

Separate analyses have been conducted for NO_x, SO_2, and PM_{10} emissions. All costs included in the BART analysis are in 2007 dollars, and costs have not been escalated to the assumed 2013 BART implementation date.

Establishing Permit Emission Levels from BART Analysis Results

As an integral part of the BART analysis process, cost and expected emission information was developed for NO_x, SO_2, and PM_{10}. This information is assembled from various sources including emission reduction equipment vendors, AEPCO operating and engineering data, and internal CH2M HILL historical information.

The level of accuracy of the cost estimate can be broadly classified as American Association of Cost Engineers (AACE) Class V or "Order of Magnitude," which can be categorized as +50 percent/-30 percent. There are several reasons for selecting this range of cost estimates to be included in the BART analysis. They are primarily a result of the difficulty in receiving detailed and accurate information from equipment vendors based on limited available data provided to the vendors. Because of the active power industry marketplace, obtaining engineering and construction information is restricted due to vendor workload. Material and construction labor costs also change rapidly in today's active economy. However, this level of cost estimate precision is adequate for comparison of control technology alternatives.

The accuracy of expected emissions may also be questionable, and is also attributable to the inability to gain timely and accurate vendor information. This is exemplified by the difficulty in obtaining background information, and the vendor time required to develop accurate emission projections for study purposes in comparison to their response to actual project request for proposals. Also, variance in expected emissions can be dependent upon the pollutant under consideration (i.e., particulate emissions can generally be more accurately predicted than NO_x emissions).

Therefore, when establishing emission limitations in permits, consideration of variability in cost and expected emissions information must be considered.

3.1.1 BART NO_x Analysis

NO_x formation in coal-fired boilers is a complex process that depends on a number of variables, including operating conditions, equipment design, and coal characteristics.

Formation of NO_x

During coal combustion, NO_x forms in three ways. The dominant source of NO_x formation is the oxidation of fuel-bound nitrogen (fuel NO_x). During combustion, part of the fuel NO_x is released from the coal with the volatile matter, and part is retained in the solid portion (char). The nitrogen chemically bound in the coal is partially oxidized to nitrogen oxides (NO and NO_2) and partially reduced to molecular nitrogen (N_2). A smaller part of NO_x formation is due to high temperature fixation of atmospheric nitrogen in the combustion air (thermal NO_x). A very small amount of NO_x is called "prompt" NO_x. Prompt NO_x results from an interaction of hydrocarbon radicals, nitrogen, and oxygen.

In a conventional pulverized coal burner, air is introduced with turbulence to promote good mixing of fuel and air, which provides stable combustion. However, not all of the oxygen in the air is used for combustion. Some of the oxygen combines with the fuel nitrogen to form NO_x.

Coal characteristics directly and significantly affect NO_x emissions from coal combustion. Coal ranking as defined by The American Society for Testing and Materials (ASTM) is a means of classifying coals according to their degree of metamorphism in the natural series, from lignite to sub-bituminous to bituminous and on to anthracite. Lower rank coals, such as the sub-bituminous coals from the Powder River Basin (PRB), produce lower NO_x emissions than higher rank bituminous coals because of their higher reactivity and lower nitrogen content. The fixed carbon to volatile matter ratio (fuel ratio), coal oxygen content, and rank are good relative indices of the reactivity of a coal. Lower rank coals release more organically bound nitrogen earlier in the combustion process than do higher rank bituminous coals. When used with low-NO_x burners (LNBs), sub-bituminous coals create a longer time for the kinetics to promote more stable molecular nitrogen, and therefore result in lower NO_x emissions.

The primary basis for coal rank classification by ASTM is fixed carbon content, volatile matter content, and gross calorific value, all determined on a moist and ash-free basis. In the cases of high volatile bituminous "C" and sub-bituminous "A," there is an overlap in the gross calorific values. To classify these types of coals, a characteristic called agglomeration is used. Agglomeration is a distinguishing characteristic that classifies the coals as bituminous rather than sub-bituminous—that is, they are "agglomerating" as compared to "non-agglomerating." Agglomerating, as applied to coal, is "the property of softening when it is heated to above about 400 degrees Celsius in a non-oxidizing atmosphere, and then appearing as a coherent mass after cooling to room temperature." Because the agglomerating property of coals is the result of particles transforming into a plastic or semi-liquid state when heated, it reflects a change in surface area of the particle. Thus, with the application of heat, agglomerating coals would tend to develop a non-porous surface, while the surface of non-agglomerating coals would become even more porous with combustion. As shown in Figure 3-1, the increased porosity provides more particle surface area, resulting in more favorable combustion conditions. This non-agglomerating property assists in making sub-bituminous coals more amenable to controlling NO_x, by allowing less air to be introduced during the initial ignition portion of the combustion process. Because ST3 may burn a blend of bituminous and sub-bituminous coals, NO_x emissions from combustion of these blended coals will vary depending on the resultant combined coal characteristics.

FIGURE 3-1
Illustration of the Effect of Agglomeration on the Speed of Coal Combustion
ST3

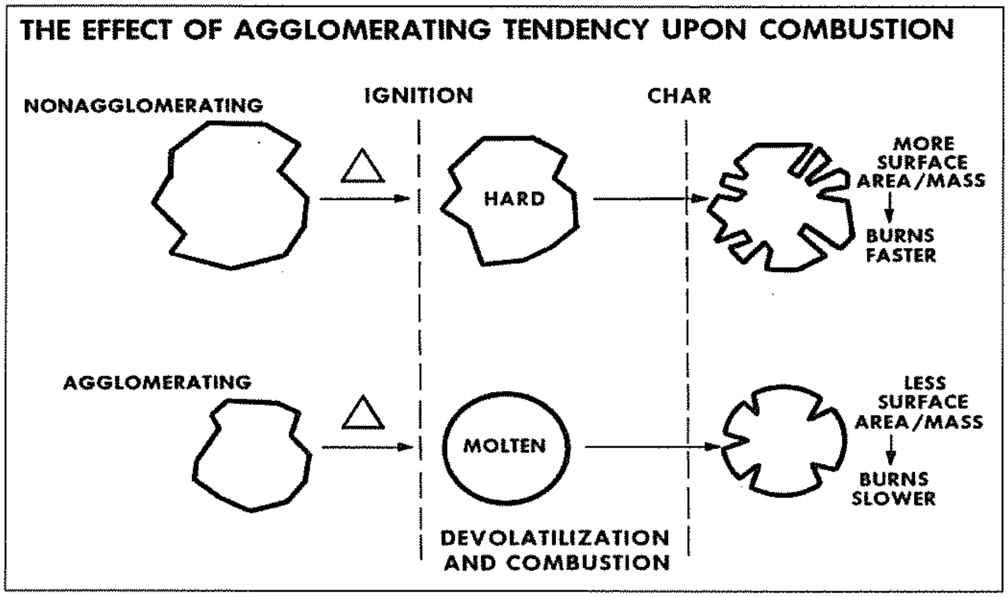


Table 3-1 shows key characteristics of the coals which are planned to be burned on ST3.

TABLE 3-1
AEPCO Coal Characteristics Comparison

Site	Btus (pounds)	Ash (%)	Sulfur (%)	Nitrogen (%)	Oxygen (%)	Coal Class
West Elk Colorado	12,120	9.5	0.58	1.42	9.70	Bituminous
Twenty-Mile Colorado	11,400	9.8	0.5	1.80	11.14	Bituminous
Elk Creek Colorado	12,196	10.84	0.61	1.55	5.11	Bituminous
ColoWyo Colorado	10,400	6.19	0.36	1.33	12.07	Sub-bituminous
Bowie #2 Colorado	12,054	7.99	0.38	1.57	6.31	Bituminous
Antelope Wyoming	8,800	5.25	0.24	0.78	12.08	Sub-bituminous
Low Jacob's Ranch Wyoming	8,781	5.49	0.4	0.72	12.58	Sub-bituminous
High Jacob's Ranch Wyoming	8,800	5.49	0.4	0.80	9.44	Sub-bituminous
Black Thunder Wyoming	8,794	5.63	0.3	0.58	11.48	Sub-bituminous
N. Ant/Rochelle Wyoming	8,800	4.4	0.2	0.90	17.02	Sub-bituminous
Lee Ranch New Mexico	9,250	17.8	0.9	1.00	10.73	Bituminous/Sub-bituminous[1]

NOTE:
[1] Lee Ranch coal analyses have shown varying coal class characteristics

As shown in Table 3-1, the bituminous coals generally exhibit higher nitrogen content and lower oxygen content than the sub-bituminous coals. The higher nitrogen content is an indication that more nitrogen is available to the combustion process and higher NO_x emissions are likely. Oxygen content can be correlated to the reactivity of the coal, with more reactive coals generally containing higher levels of oxygen. More reactive coals tend to produce lower NO_x emissions, and they are also more conducive to reduction of NO_x emissions through the use of combustion control measures, such as LNBs and over-fire air (OFA). These characteristics indicate that higher NO_x formation is likely with bituminous rather than sub-bituminous coals.

Coal quality characteristics also impact the design and operation of the boiler and associated auxiliary equipment. Minor changes in quality can sometimes be accommodated through operational adjustments or changes to equipment. It is important to note, however, that consistent variations in quality or assumptions of "average" quality for performance projections can be problematic. This is particularly troublesome when dealing with performance issues that are very sensitive to both coal quality and combustion conditions, such as NO_x formation. There is significant variability in the quality of coals burned at ST3.

Several of the coal quality characteristics and their effect on NO_x formation have been previously discussed. There are additional considerations that illustrate the complexity of achieving and maintaining consistent low NO_x emissions with pulverized coal on a shorter term, such as a 30-day rolling average basis.

Good combustion is based on the "three Ts:" time, temperature and turbulence. These parameters along with a "design" coal are taken into consideration when designing a boiler and associated firing equipment such as fans, burners, and pulverizers. If a performance requirement such as NO_x emission limits is subsequently changed, conflicts with other performance issues can result.

ST3 is located at an altitude of 4,200 feet above sea level. At this elevation, atmospheric pressure is lower as compared with sea level pressure of 14.7 pounds per square inch. This lower pressure means that less oxygen is available for combustion for each volume of air. To provide adequate oxygen to meet the requirements for efficient combustion, larger volumes of air are required. When adjusting air flows and distribution to lower NO_x using LNBs and OFA or under-fire air (UFA), original boiler design restrictions again limit the modifications that can be made and still achieve satisfactory combustion performance.

Another significant factor in controlling NO_x emissions is the fineness of the coal entering the burners. Fineness is influenced by the grindability index (Hardgrove) of the coal. Finer coal particles promote release of volatiles and assist char burnout due to more surface area exposed to air. NO_x reduction with high-volatile coals is improved with greater fineness and with proper air staging. The lower rank sub-bituminous coals such as PRB coals are quite friable and easy to grind. Coals with lower Hardgrove Grindability Index values, are more difficult to grind and can contribute to higher NO_x levels. In addition, coal fineness can deteriorate over time periods between pulverizer maintenance and service as pulverizer grinding surfaces wear.

In summary, when all the factors of agglomeration versus non-agglomeration, nitrogen and oxygen content of the coals, and the grindability index are taken into account, this analysis demonstrates that, for the wide variability of coal supply to be used at ST3, the more appropriate presumptive BART limit is 0.32 lb/MMBtu. This limit is referred to here only as a point of reference, and CH2M HILL recommends that this value be used in evaluation of the effectiveness of BART controls applied to ST3. The BART analysis for NO_x emissions from ST3 is further described below.

Step 1: Identify All Available Retrofit Control Technologies

The first step of the BART process is to evaluate NO_x control technologies with practical potential for application to ST3, including those control technologies identified as best available control technology (BACT) or lowest achievable emission rate (LAER) by permitting agencies across the United States. A broad range of information sources have been reviewed in an effort to identify potentially applicable emission control technologies.

ST3 NO_x emissions are currently controlled through the use of OFA and UFA systems added to the burners. ST3 is a dry turbo-fired boiler, with 12 Riley directional flame burners.

The following potential NO_x control technology options were considered:

- New/modified state-of-the-art LNBs with advanced OFA
- Rotating opposed fire air (ROFA)
- Selective non-catalytic reduction system (Rotamix and SNCR)
- Selective catalytic reduction (SCR) system
- Neural Network/Boiler Combustion Control (Neural Net)

Step 2: Eliminate Technically Infeasible Options

For ST3, a dry turbo-fired configuration burning a blend of bituminous and sub-bituminous coals, technical feasibility will primarily be determined by physical constraints, boiler configuration, and on the ability to achieve the regulatory presumptive limit (used as a guide) of 0.32 lb/MMBtu of NO_x. ST3 currently has an average NO_x emission rate of 0.43 lb/MMBtu.

For this BART analysis, information pertaining to LNBs, OFA, SNCR, and SCR were based on a combination of vendor information and internal CH2M HILL information. Sources of cost estimates for ST3 are listed below in Table 3-2, which also summarizes the control technology options evaluated in this BART analysis, along with projected NO_x emission rates. All technologies listed can meet the bituminous presumptive BART limit of 0.32 lb/MMBtu, except for the neural net boiler controls.

TABLE 3-2
NO_x Control Technology Emission Rate Ranking
ST3

Technology	Source of Estimated Cost and Emissions	Expected Emission Rate (lb/MMBtu)
Presumptive BART Limit		0.32
LNB with OFA	Babcock Power	0.31
ROFA	Mobotec	0.26
ROFA with Rotamix	Mobotec	0.18
LNB with OFA and SNCR	Babcock Power, Fuel Tech	0.23
LNB with OFA and SCR	Babcock Power, CH2M HILL	0.07
Neural Net Controls [a]	NeuCo	0.37

NOTE:
[a] NeuCo provides no guarantees; derived using 15 percent reduction from baseline NO_x emissions level.

Step 3: Evaluate Control Effectiveness of Remaining Control Technologies

Preliminary vendor proposals, such as those used to support portions of this BART analysis, may be technically feasible and provide expected or guaranteed emission rates; however, they include inherent uncertainties. These proposals are usually prepared in a limited time frame, may be based on incomplete information, may contain over-optimistic conclusions, and are non-binding. Therefore, emission rate values obtained in such preliminary proposals must be qualified, and it must be recognized that contractual guarantees are established only after more detailed analysis has been completed.

Level of Confidence for Vendor Post-Control NO_x Emissions Estimates. To determine the level of NO_x emissions needed to consistently achieve compliance with an established goal, a review of typical NO_x emissions from coal-fired generating units was completed. As a result of this review, it was noted that NO_x emissions can vary significantly around an average emissions level. This variance can be attributed to many reasons, including coal characteristics, unit load, boiler operation including excess air, boiler slagging, burner equipment condition, coal mill fineness, and so forth.

The steps used to determine a level of confidence for the vendor expected value are as follows:

1. Establish expected NO_x emissions value from vendor.
2. Evaluate vendor experience and historical basis for meeting expected values.
3. Review and evaluate unit physical and operational characteristics and restrictions. The fewer variations there are in operations, coal supply, etc., the more predictable and less variant the NO_x emissions are.
4. For each technology expected value, there is a corresponding potential for actual NO_x emissions to vary from this expected value. From the vendor information presented, along with anticipated unit operational data, an adjustment to the expected value can be made.

The following subsections describe the NO_x control technologies and the control effectiveness evaluated in this BART analysis.

New LNBs with OFA System. The mechanism used to lower NO_x with LNBs is to stage the combustion process and provide a fuel-rich condition initially; this is so oxygen needed for combustion is not diverted to combine with nitrogen and form NO_x. Fuel-rich conditions favor the conversion of fuel NO_x to N_2 instead of NO_x. Additional air (OFA or UFA) is then introduced upstream or downstream in a lower temperature zone to burn out the char.

Both LNBs and OFA are considered to be a capital cost, combustion technology retrofit that may require boiler water wall tube replacement. Information provided to CH2M HILL by Babcock Power indicates that new LNB, OFA, UFA, and windbox modifications at ST3 would result in an expected NO_x emission rate of 0.31 lb/MMBtu. This emission rate represents a significant reduction from the current NO_x emission rate, and is below the EPA-presumptive NO_x emission rate for bituminous coal of 0.32 lb/MMBtu.

ROFA. Mobotec markets ROFA as an improved second generation OFA system. Mobotec states that "the flue gas volume of the furnace is set in rotation by asymmetrically placed air nozzles." Rotation is reported to prevent laminar flow and improve gas mixing, so that the entire volume of the furnace can be used more effectively for the combustion process. In addition, the swirling action reduces the maximum temperature of the flames and increases heat absorption. Mobotec expects that enhanced mixing will also result in reduction in hot and cold furnace zones, improved heat absorption and boiler efficiency, and lower carbon monoxide (CO) and NO_x emissions.

A typical ROFA installation will have a booster fan(s) to supply the high-velocity air to the ROFA boxes. Mobotec proposed one 2,100 horsepower fan for ST3 located at grade, which would provide hot air at all boiler loads.

Using ROFA technology, Mobotec offered an estimated NO_x emission rate of 0.26 lb/MMBtu. Under the Mobotec proposal, the operation of existing burners and OFA ports will be analyzed; however, the OFA ports are not planned for use and would likely be blocked off. While a typical installation does not require modification to the existing burners, some modification may be necessary. Computational fluid dynamics modeling will determine the quantity and location of new ROFA ports. Mobotec does not typically provide installation services because they believe that the owner can more cost-effectively contract for these services, however they did provide a budgetary price for installation labor. Mobotec provides one onsite construction supervisor during installation and startup.

SNCR. With SNCR, an amine-based reagent such as ammonia—or more commonly urea—is injected into the furnace within a temperature range of 1,600 degrees Fahrenheit (° F) to 2,100°F, where it reduces NO_x to nitrogen and water. NO_x reductions of up to 40 to 60 percent have been achieved, although 15 to 30 percent is more realistic for most applications. SNCR is typically applied on smaller units. Adequate reagent distribution in the furnaces of large units can be problematic.

Reagent utilization, which is a measure of the efficiency with which the reagent reduces NO_x, can range from 20 to 60 percent, depending on the amount of reduction, unit size, operating conditions, and allowable ammonia slip. With low reagent utilization, low temperatures, or inadequate mixing, ammonia slip occurs, allowing unreacted ammonia to create problems downstream. The ammonia may render fly ash unsalable, and also react with sulfur to form ammonium bisulphate, which can foul heat exchanger surfaces or create a visible stack plume. Reagent utilization can have a significant impact on economics, with higher levels of NO_x reduction generally resulting in lower reagent utilization and higher operating cost. Reductions from higher baseline inlet NO_x concentrations are lower in cost per ton, but result in higher operating costs, due to greater reagent consumption.

Mobotec also provided information for their Rotamix SNCR system for ST3. The expected NO_x emission rate for the Rotamix system, operating in conjunction with ROFA, is 0.18 lb/MMBtu. A budgetary proposal was also received from Fuel Tech for their urea-based SNCR system.

SCR. SCR works on the same chemical principle as SNCR but SCR uses a catalyst to promote the chemical reaction. Ammonia or urea is injected into the flue-gas stream, where it reduces NO_x to nitrogen and water. Unlike the high temperatures required for SNCR, in SCR the reaction takes place on the surface of a vanadium/titanium-based catalyst at a temperature range between 580°F to 750°F. Due to the catalyst, the SCR process is more efficient than SNCR and results in lower NO_x emissions. The most common type of SCR is the high-dust configuration, where the catalyst is located downstream from the boiler economizer and upstream of the air heater and any particulate control equipment. In this location, the SCR is exposed to the full concentration of fly ash in the flue gas that is leaving the boiler. However, for ST3, the SCR could be installed after the hot-side ESP and before the air heater; therefore a low-dust configuration is assumed. In a full-scale SCR, the flue ducts are routed to a separate large reactor containing the catalyst. With in-duct SCR, the catalyst is located in the existing gas duct, which may be expanded in the area of the catalyst to reduce flue gas flow velocity and increase flue gas residence time. Due to the higher removal rate, a full-scale SCR was used as the basis for analysis at ST3.

As with SNCR, it is generally more cost effective to reduce NO_x emission levels as much as possible through combustion modifications to minimize the catalyst surface area and ammonia requirements of the SCR.

Neural Net Controls/Boiler Combustion Control. Review of neural net and improved boiler combustion control are combined for purposes of this analysis under the potential implementation of neural net boiler control system. Information regarding neural net controls was previously received from NeuCo, Inc. While NeuCo offers several neural net products, CombustionOpt and SootOpt provide the potential for NO_x reduction. NeuCo stated these products can be used on most control systems, and can be effective even in conjunction with other NO_x reduction technologies.

NeuCo predicts that CombustionOpt can reduce NO_x by 15 percent, and SootOpt can provide an additional 5 to 10 percent. Because NeuCo does not offer guarantees on this projected emission reduction, a nominal reduction of 15 percent was assumed for evaluation purposes. The budgetary price for CombustionOpt and SootOpt were $150,000 and $175,000 respectively, with an addition $200,000 cost for a process link to the unit control system.

Because NeuCo does not guarantee NO_x reduction, the estimated emission reduction levels provided can not be considered as reliable projections. Therefore, neural net should be considered as a supplementary or "polishing" technology, but not on a "stand-alone" basis.

Step 4: Evaluate Impacts and Document the Results

This step involves the consideration of energy, environmental, and economic impacts associated with each control technology. The remaining useful life of the plant is also considered during the evaluation.

Energy Impacts. Installation of LNBs and modification to the existing OFA and UFA systems are not expected to significantly impact the boiler efficiency or forced-draft fan power usage. Therefore, these technologies are not expected to have significant energy impacts.

The Mobotec ROFA system requires installation and operation of one 2,100 horsepower ROFA fan (1,566 kilowatts [kW] total). Fuel Tech provided an estimate of 130 kW of additional auxiliary power, and the same estimate was used for Rotamix. SCR retrofit impacts the existing flue gas fan systems, due to the additional pressure drop associated with the catalyst, which is typically a 6- to 8-inch water gage increase.

Environmental Impacts. Mobotec generally predicts that CO emissions, and unburned carbon in the ash, commonly referred to as los on ignition (LOI), would be the same or lower than prior levels for the ROFA system.

SNCR and SCR installation could impact the salability and disposal of fly ash due to ammonia levels, and could potentially create a visible stack plume, which may negate other visibility improvements. Other environmental impacts involve the potential public and employee safety hazard associated with the storage of ammonia, especially anhydrous ammonia, and the transportation of the ammonia to the power plant site.

Economic Impacts. A comparison of the technologies on the basis of costs, design control efficiencies, and tons of NO_x removed is summarized in Table 3-3, and the first year control costs are shown in Figure 3-2. The complete Economic Analysis is contained in Appendix A.

TABLE 3-3
NO_x Control Cost Comparison
Apache Unit 3

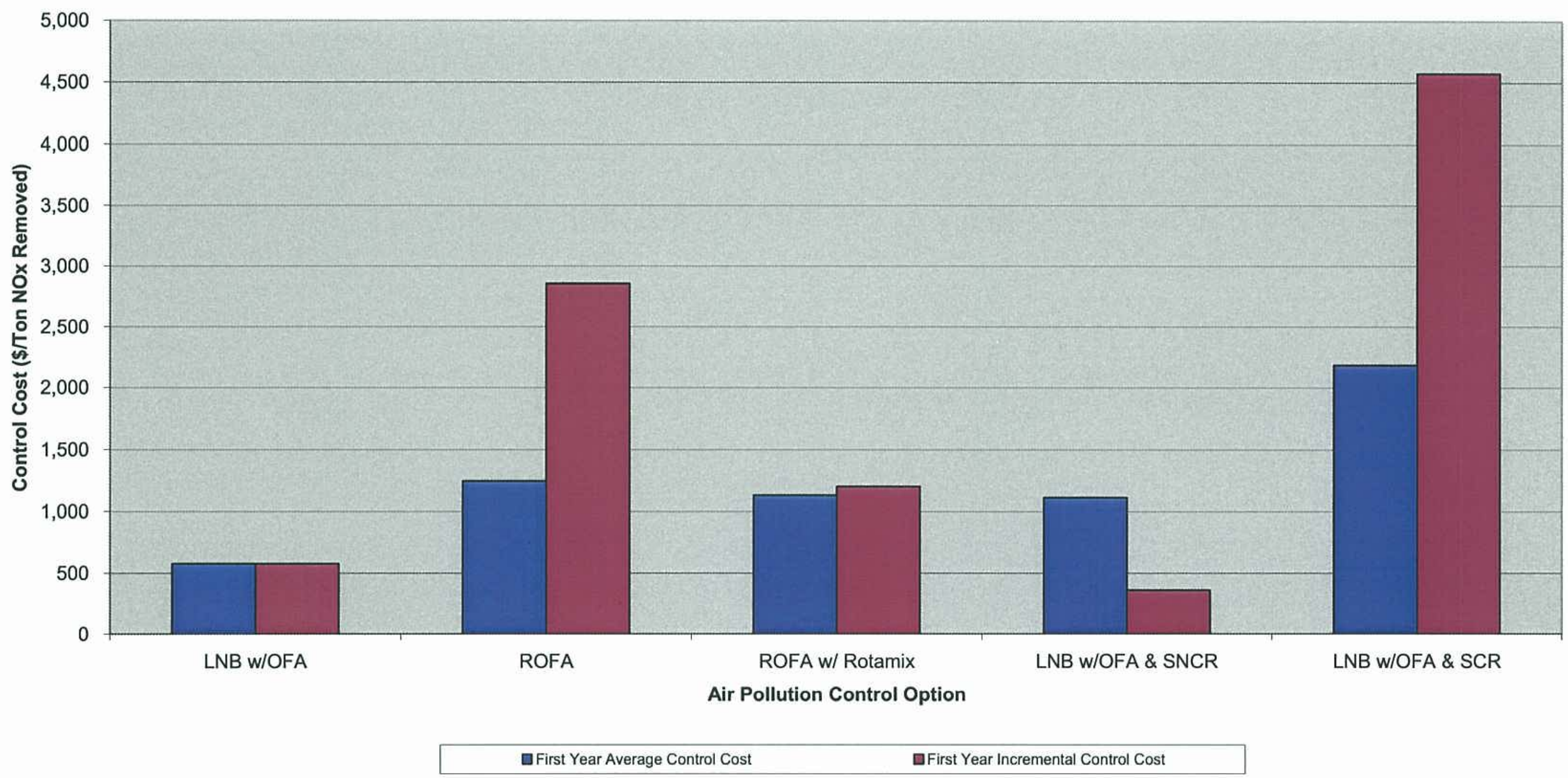
Factor	LNB with OFA	ROFA	ROFA with Rotamix	LNB with OFA and SNCR	LNB with OFA and SCR
Major Materials Design Costs	$2,000,000	$3,627,000	$5,440,500	$6,830,000	$29,300,000
Total Installed Capital Costs	$4,760,000	$9,616,084	$12,623,773	$12,541,130	$48,740,300
Total First Year Fixed and Variable O&M Costs	$80,000	$719,484	$980,961	$524,622	$1,425,743
Total First Year Annualized Cost	$532,808	$1,634,241	$2,181,833	$1,717,633	$6,062,301
Power Consumption (MW)	–	1.57	2.07	0.50	1.00
Annual Power Usage (Kilowatt-Hr/Year)	–	12.0	15.8	3.8	7.7
NO_x Design Control Efficiency	27.9%	39.5%	58.1%	46.5%	83.7%
Tons NO_x Removed per Year	926	1,312	1,929	1,543	2,778
First Year Average Control Cost ($/Ton of NO_x Removed)	575	1,246	1,131	1,113	2,183
Incremental Control Cost ($/Ton of NO_x Removed)	575	2,855	1,203	360	4,572

Preliminary BART Selection. The four-step evaluation indicates new LNBs with OFA and UFA would represent BART for ST3 based on its significant reduction in NO_x emissions, reasonable control cost, and no additional power requirements or environmental impacts. LNB with OFA meets the target EPA-presumptive limit of 0.32 lb/MMBtu for bituminous coal.

Step 5: Evaluate Visibility Impacts

Please see Section 4.0, BART Modeling Analysis.

FIGURE 3-2
First Year Control Cost for NOx Air Pollution Control Options
ST3



3.1.2 BART SO_2 Analysis

SO_2 forms in the boiler during the combustion process from the oxidation of the sulfur present in the coal, and is primarily dependent on coal sulfur content. The BART analysis for SO_2 emissions on ST3 is described below.

Step 1: Identify All Available Retrofit Control Technologies

A broad range of information sources were reviewed in an effort to identify potentially applicable emission control technologies for SO_2 at ST3. This included control technologies identified as BACT or LAER by permitting agencies across the United States.

The following potential SO_2 control technology option was considered:

- Enhancement of current wet limestone scrubber or SDAS

ST3 currently operates a wet limestone scrubber for SO_2 removal, with current emissions of 0.151 lb/MMBtu. The EPA BART guidelines state that for existing units with SO_2 controls achieving at least 50 percent SO_2 removal, cost-effective scrubber upgrades should be considered. EPA recommends consideration of the following potential upgrades:

- Elimination of bypass reheat
- Installation of liquid distribution rings
- Installation of perforated trays
- Use of organic acid additives
- Improve or upgrade scrubber auxiliary system equipment
- Redesign spray header or nozzle

Step 2: Eliminate Technically Infeasible Options

Technical feasibility will primarily be based on the regulatory presumptive limit (used as a guideline) of 95 percent reduction in SO_2 emissions, or 0.15 lb/MMBtu. Because ST3 is currently operating with an SO_2 emissions rate of approximately 0.151 lb/MMBtu, only a very small increase in scrubber efficiency would meet a target of 0.15 lb/MMBtu.

Over the past several years AEPCO has completed several scrubber upgrades to improve performance, including the following:

- Elimination of flue gas bypass
- Splitting the limestone feed to both the absorber feed tank and tower sump
- Upgrade of the mist eliminator system
- Installation of suction screens at pump intakes
- Automation of pump drain valves
- Replacement of scrubber packing with perforated stainless steel trays

Dibasic acid additive was tested; however results did not show significantly higher SO_2 removal.

Additional improvements to the existing limestone scrubber system may be feasible, which could improve overall performance. At this time it is not known what those additional improvements may be, so costs for this option are not included in this report.

Step 3: Evaluate Control Effectiveness of Remaining Control Technologies

When evaluating the control effectiveness of SO_2 reduction technologies, each option can be compared against benchmarks of performance. One such benchmark is the presumptive BART emission limit. As indicated previously, the presumptive limit for SO_2 on a BART-eligible coal-burning unit, used here as a point of reference, is 95 percent removal, or 0.15 lb/MMBtu.

Step 4: Evaluate Impacts and Document the Results

This step involves the consideration of energy, environmental, and economic impacts associated with each control technology. The remaining useful life of the plant is also considered during the evaluation.

Energy Impacts. Upgraded operation of the existing SDAS system is not expected to result in any additional power consumption.

Environmental Impacts. There will be incremental additions to scrubber waste disposal and makeup water requirements and a reduction of the stack gas temperature if there is elimination of flue gas bypass.

Economic Impacts. There are no anticipated cost impacts attributable to upgraded scrubber operation.

Preliminary BART Selection. The four-step evaluation indicates the completed upgrade of the existing wet limestone scrubber, or SDAS, represents BART for ST3 for SO_2 emissions. There are no anticipated capital costs or additional power requirements associated with this option, and minimal environmental impacts.

Step 5: Evaluate Visibility Impacts

Please see Section 4.0, BART Modeling Analysis.

3.1.3 BART PM_{10} Analysis

ST3 is currently equipped with a hot-side ESP. ESPs remove particulate matter from the flue gas stream by electrically charging fly ash particles with a very high direct current voltage, and attracting these charged particles to grounded collection plates. A layer of collected particulate matter forms on the collecting plates and is removed by periodically rapping the plates. The collected ash particles drop into hoppers below the precipitator and are removed periodically by the fly ash-handling system.

Historically, outlet ESP particulate emissions on ST3 have ranged from approximately 0.007 to 0.045 lb/MMBtu. This wide range in outlet emissions can in part be attributed to the hot-side operation, as well as the wide variety of coals being burned in the ST3 boiler. Hot-side ESP effectiveness may be impacted by sodium content in the ash.

The BART analysis for PM_{10} emissions at ST3 is described below. For the modeling analysis in Section 4.0, PM_{10} is used as an indicator for particulate matter, and PM_{10} includes particulate matter less than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$) as a subset.

Step 1: Identify All Available Retrofit Control Technologies

Three retrofit control technologies have been identified for additional particulate matter control:

- Performance upgrades to existing hot-side ESP
- Replace current ESP with fabric filter unit
- Polishing fabric filter after ESP

Step 2: Eliminate Technically Infeasible Options

Performance Upgrades. Modifications to the hot-side ESP such as improving the rapping system, controller upgrades, conversion to cold-side operation, flue gas conditioning, wide plate spacing, addition of particle pre-charging system, etc., can be implemented to improve ESP particulate collection efficiency.

Replacement Fabric Filter. A full-size pulse jet fabric filter could be installed as a replacement for the existing ESP on ST3. This fabric filter would be sized for approximately 3.5 or 4:1 Air to Cloth (A/C) ratio (actual cubic feet per minute of flue gas per square feet of fabric). An A/C ratio of 4:1 was used for this analysis. Fabric filters have been proven to provide highly effective and consistent particulate emissions reduction, with outlet emissions of approximately 0.015 lb/MMBtu. The ESP would be removed from service with this replacement fabric filter option.

Polishing Fabric Filter. A polishing fabric filter could be added downstream of the existing ESP at ST3. One such technology is licensed by the Electric Power Research Institute, and referred to as a COHPAC (Compact Hybrid Particulate Collector). The COHPAC collects the ash that is not collected by the ESP, thus acting as a polishing device. The ESP needs to be kept in service for the COHPAC fabric filter to operate effectively.

The COHPAC fabric filter is about one-half to two-thirds the size of a full-size fabric filter. Because the COHPAC has a higher A/C ratio (as high as 6 to 8:1), compared to a full-size pulse jet fabric filter (3.5 to 4:1), an A/C ratio of 6:1 was used for this analysis.

Step 3: Evaluate Control Effectiveness of Remaining Control Technologies

The existing ESP at ST3 is achieving a controlled particulate matter emission rate as high as 0.045 lb/MMBtu. Adding a replacement fabric filter, or a COHPAC fabric filter downstream of the existing ESP, PM_{10} emissions are expected to be approximately 0.015 lb/MMBtu. As AEPCO has yet to conduct an evaluation of the performance upgrades that could be applied to the existing ESPs, a post-upgrade emissions level cannot be determined at this time. Considering existing performance levels and performance levels associated with the fabric filter options, it is expected that any ESP enhancements would result in PM_{10} emissions between 0.045 lb/MMBtu and 0.015 lb/MMbtu.

The PM_{10} control technology emission rates are summarized in Table 3-4, with the same PM_{10} emissions rate expected from both replacement and polishing fabric filters.

TABLE 3-4
PM_{10} Control Technology Emission Rates
ST3

Control Technology	Expected PM_{10} Emission Rate (lb/MMBtu)
Replacement Fabric Filter	0.015
Polishing Fabric Filter	0.015
Precipitator Upgrades	0.015 to 0.045

Step 4: Evaluate Impacts and Document the Results

This step involves the consideration of energy, environmental, and economic impacts associated with each control technology. The remaining useful life of the plant is also considered during the evaluation.

Energy Impacts. Energy is required to overcome the additional pressure drop from both the fabric filter replacement and COHPAC fabric filter, and associated ductwork. Therefore, fan upgrades may be required for both alternatives to overcome the additional pressure drop. An estimated 6 to 8 inches of water pressure drop for the replacement fabric filter may be experienced, with 8 to 10 inches of water likely for the COHPAC unit. The polishing fabric filter will also result in maintaining the existing ESP in service, which will result in power consumption in addition to what is required by the fabric filter replacement option.

A COHPAC fabric filter at ST3 would require approximately 1.3 MW of power.

Energy impacts will vary depending on the precipitator upgrade applied.

Environmental Impacts. There are no negative environmental impacts from precipitator upgrades, the addition of a replacement or COHPAC polishing fabric filter.

Economic Impacts. A comparison of the costs and PM_{10} removed for a replacement fabric filter or COHPAC polishing fabric filter are shown in Table 3-5, with a graph of first year costs shown in Figure 3-2. Specific costs for the precipitator upgrades were not evaluated as AEPCO has yet to evaluate the upgrades that may be applicable to ST3. It is assumed, however, these costs would be less than a new replacement fabric filter or COHPAC unit. Capital cost information was provided by Alstom for both the polishing and replacement fabric filters. The complete Economic Analysis is contained in Appendix A.

TABLE 3-5
PM_{10} Control Cost
Apache Unit 3

Factor	Polishing Fabric Filter	Fabric Filter
Major Materials and Design Costs	$6,666,667	$10,000,000
Total Installed Capital Costs	$15,866,667	$23,800,000
Total First Year Fixed and Variable O&M Costs	$682,996	$604,552

TABLE 3-5
PM_{10} Control Cost
Apache Unit 3

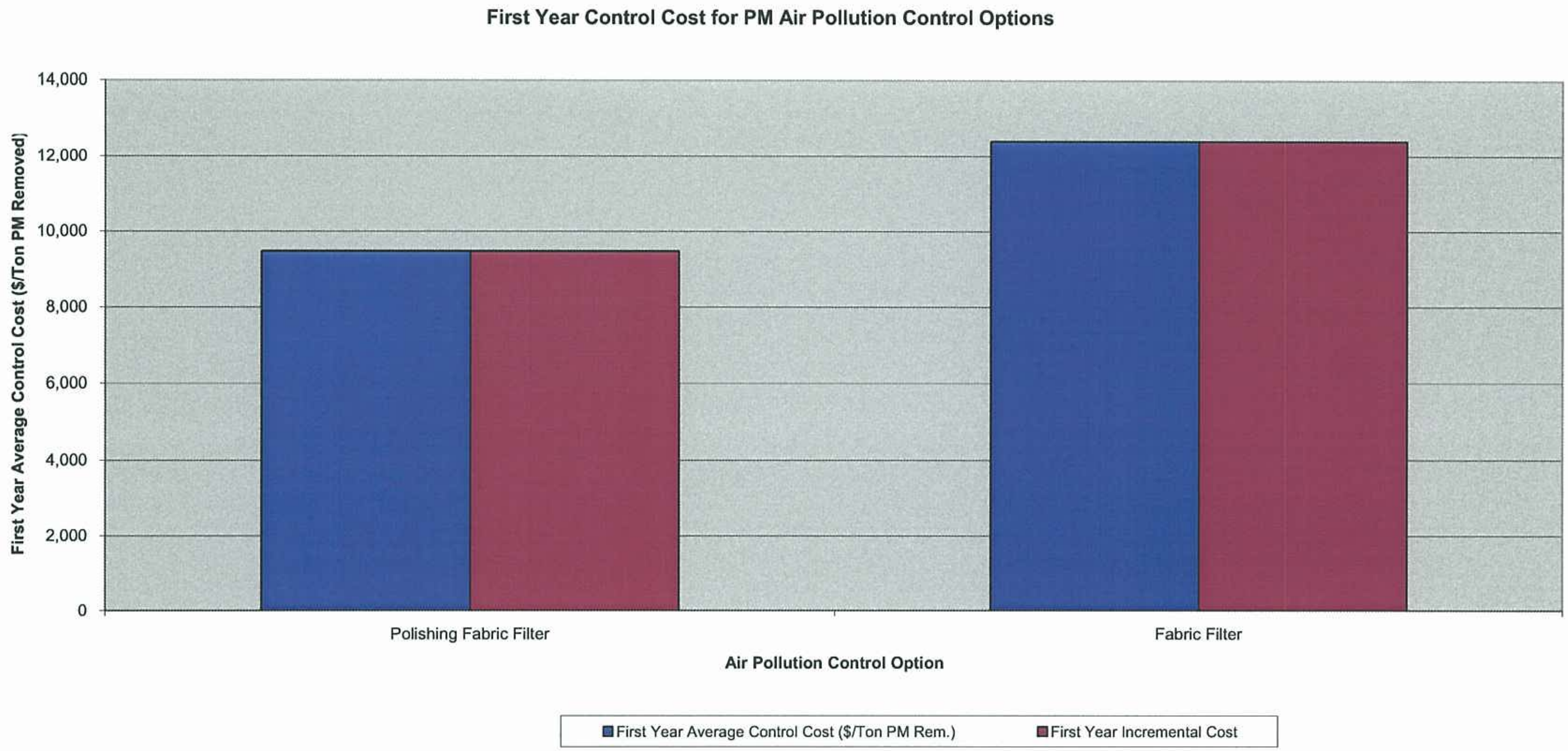
Factor	Polishing Fabric Filter	Fabric Filter
Total First Year Annualized Cost	$2,192,357	$2,868,595
Power Consumption (MW)	1.30	1.00
Annual Power Usage (kW-Hr per Year)	10.0	7.7
Particulate matter Design Control Efficiency	66.67%	66.67%
Tons Particulate Matter Removed per Year	231	231
First Year Average Control Cost ($/Ton of Particulate Matter Removed)	9,471	12,393
Incremental Control Cost ($/Ton of Particulate Matter Removed)	9,471	12,393

Preliminary BART Selection. The four-step evaluation indicates high control costs are associated with installation of either replacement fabric filter or a polishing fabric filter (COHPAC). Based on these high costs, preliminary evaluation indicates precipitator upgrades represent BART for ST3. Precipitator upgrades are anticipated to reduce particulate matter emissions and have a more reasonable control cost and no associated environmental impacts.

Step 5: Evaluate Visibility Impacts

Please see Section 4.0, BART Modeling Analysis.

FIGURE 3-3
First Year Control Cost for Particulate Matter Air Pollution Control Options
ST3



Section 4.0
BART Modeling Analysis

4.0 BART Modeling Analysis

4.1 Introduction

This section presents the dispersion modeling methods and results for estimating the degree of visibility improvement from BART control technology options for the AEPCO ST3.

To a large extent, the modeling followed the methodology outlined in the WRAP protocol for performing BART analyses (WRAP, 2006). Any proposed deviations from that methodology are documented in this report.

4.2 Model Selection

CH2M HILL used the EPA-required CALPUFF modeling system to assess the visibility impacts at Class I areas. CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that simulates the effects of time- and space-varying meteorological conditions on pollution transport, transformation and removal. BART guidance says, "CALPUFF is the best regulatory modeling application currently available for predicting a single source's contribution to visibility impairment and is currently the only EPA-approved model for use in estimating single source pollutant concentrations resulting from the long range transport of pollutants."

The CALPUFF modeling system includes the meteorological data preprocessing program for CALPUFF (CALMET) with algorithms for chemical transformation and deposition, and a post processor capable of calculating concentrations, visibility impacts, and deposition (CALPOST). The CALPUFF modeling system was applied in a full, refined mode.

CH2M HILL used the latest version (Version 6) of the CALPUFF modeling system preprocessors and models in lieu of the EPA-approved versions (Version 5). The FLM and others have noted that the EPA-approved Version 5 contained errors and that a newer version should be used. Consequently, it was decided to use the latest (as of April 2006) version of the CALPUFF modeling system (available at www.src.com):

- CALMET Version 6.211 Level 060414
- CALPUFF Version 6.112 Level 060412

CALMET, CALPUFF, CALPOST, and POSTUTIL were recompiled with the Lahey/Fujitsu Fortran 95 Compiler (Release 7.10.02) to accommodate the large CALMET domain. The recompiled processors were tested against the test case results provided with the source code (TRC, 2007), and the difference between the results was 0.03 percent.

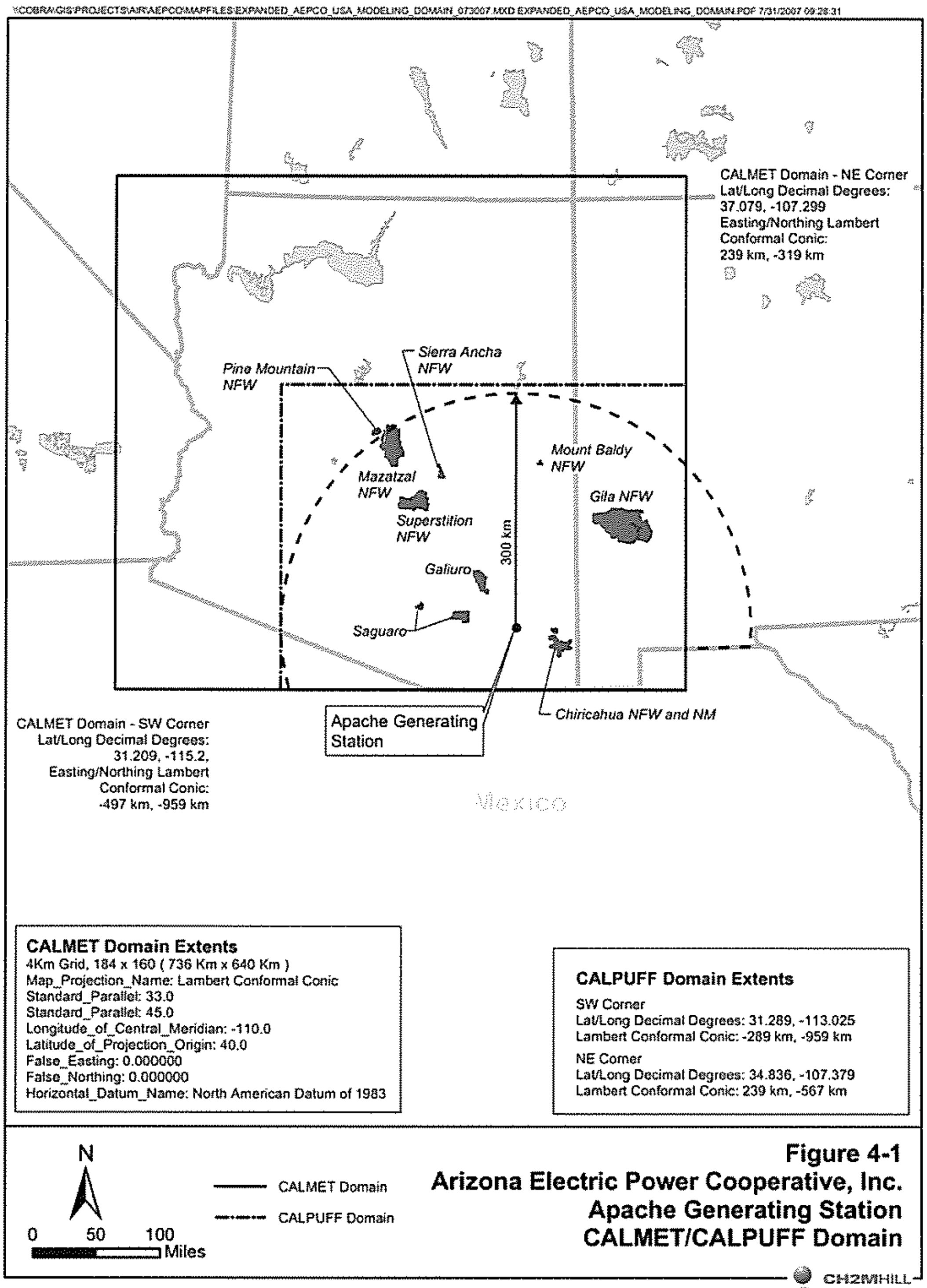
4.3 CALMET Methodology

4.3.1 Dimensions of the Modeling Domain

CH2M HILL defined domains for Mesoscale Meteorological Model, Version 5 (MM5), CALMET, and CALPUFF that were slightly different than those established for the Arizona BART modeling in WRAP (2006). In addition, the CALMET and CALPUFF Lambert Conformal Conic (LCC) map projection used in this analysis is based on a central meridian of 110° W rather than 97° W. This puts the central meridian near the center of the domain.

CH2M HILL used the CALMET model to generate three-dimensional wind fields and other meteorological parameters suitable for use by the CALPUFF model. A CALMET modeling domain has been defined to allow for at least a 50-kilometer buffer around all Class I areas within 300 kilometers of the Apache Power Plant. Grid resolution for this domain was 4 kilometers. Figure 4-1 shows the extent of the modeling domain.

FIGURE 4-1
CALPUFF and CALMET Modeling Domains



The technical options recommended in WRAP (2006) were used for CALMET. Vertical resolution of the wind field included 11 layers, with vertical cell face heights as follows (in meters):

- 0, 20, 100, 200, 350, 500, 750, 1000, 2000, 3000, 4000, 5000

Also, following WRAP (2006), ZIMAX were set to 4,500 meters based on the Colorado Department of Health and Environment (CDPHE) analyses of soundings for summer ozone events in the Denver area (CDPHE, 2005). The CDPHE analysis suggests mixing heights in the Denver area are often well above the CALMET default value of 3,000 meters during the summer. For example, on some summer days, ozone levels are elevated to 6,000 meters mean sea level or beyond during some meteorological regimes, including some regimes associated with high-ozone episodes. It is assumed that, as in Denver, mixing heights in excess of the 3,000 meters AGL CALMET default maximum would occur in the domain used for this analysis.

Table 4-1 lists the key user-specified options.

TABLE 4-1
User-Specified CALMET Options

Description	CALMET Input Parameter	Value
	CALMET Input Group 2	
Map projection	PMAP	LCC
Grid spacing	DGRIDKM	4
Number vertical layers	NZ	11
Top of lowest layer (meters)		20
Top of highest layer (meters)		5000
	CALMET Input Group 4	
Observation mode	NOOBS	1
	CALMET Input Group 5	
Extrapolation of surface wind observations	IEXTRP	4
Prognostic or MM-FDDA data switch	IPROG	14
Max surface over-land extrapolation radius (kilometers)	RMAX1	50
Max aloft over-land extrapolations radius (kilometers)	RMAX2	50
Radius of influence of terrain features (kilometers)	TERRAD	10
Relative weight at surface of Step 1 field and obs	R1	25
Relative weight aloft of Step 1 field and obs	R2	25
	CALMET Input Group 6	
Maximum over-land mixing height (meters)	ZIMAX	4500

4.3.2 CALMET Input Data

CH2M HILL ran the CALMET model to produce 3 years of analysis: 2001, 2002, and 2003. CH2M HILL used MM5 data as the basis for the CALMET wind fields. The horizontal resolution of the MM5 data is 36 kilometers.

For 2001, CH2M HILL used MM5 data at 36-kilometers resolution that were obtained from the contractor (Alpine Geophysics) who developed the nationwide data for the EPA. For 2002, CH2M HILL used 36-kilometers MM5 data obtained from Alpine Geophysics, originally developed for the WRAP. Data for 2003 (also from Alpine Geophysics), at 36-kilometers resolution, were developed by the Wisconsin Department of Natural Resources, the Illinois Environmental Protection Agency, and the Lake Michigan Air Directors Consortium (Midwest RPO).

The MM5 data were used as input to CALMET as the "initial guess" wind field. The initial guess field was adjusted by CALMET for local terrain and land use effects to generate a Step 1 wind field, and then further refined using local surface observations to create a final Step 2 wind field.

Surface data for 2001 through 2003 were obtained from the National Climatic Data Center. In addition, concurrent surface data collected at the Apache Generating Station were also included in developing the CALMET data. CH2M HILL processed data for all stations from the National Weather Service's (NWS) Automated Surface Observing System network that are in the domain. The surface data were obtained in abbreviated DATSAV3 format. A conversion routine available from the TRC website was used to convert the DATSAV3 files to CD 144 format for input to the SMERGE preprocessor and CALMET.

Land use and terrain data were obtained from the U.S. Geological Survey (USGS). Land use data were obtained in Composite Theme Grid format from the USGS, and the Level I USGS land use categories were mapped into the 14 primary CALMET land use categories. Surface properties, such as albedo, Bowen ratio, roughness length, and leaf area index, were computed from the land use values. Terrain data were taken from USGS 1 degree Digital Elevation Model data, which are primarily derived from USGS 1:250,000 scale topographic maps. Missing land use data were filled with a value that is appropriate for the missing area.

Precipitation data were ordered from the National Climatic Data Center. All available data in fixed-length, TD-3240 format were ordered for the modeling domain. The list of available stations and stations that have collected complete data varies by year, but CH2M HILL processed all available stations/data within the domain for each year. Precipitation data were prepared with the PXTRACT/PMERGE processors in preparation for use within CALMET.

Following the methodology recommended in WRAP (2006), no observed upper-air meteorological observations were used as they are redundant to the MM5 data and may introduce spurious artifacts in the wind fields. In the development of the MM5 data, the twice-daily upper-air meteorological observations were used as input with the MM5 model. The MM5 estimates were nudged to the upper-air observations as part of the Four Dimensional Data Assimilation. This results in higher temporal (hourly versus 12-hour) and spatial (36 kilometers versus ~300 kilometers) resolution for the upper-air meteorology in the MM5 field. These MM5 data are more dynamically balanced than those contained in the upper-air observations. Therefore, the use of the upper-air observations with CALMET is not needed, and in fact, will upset the dynamic balance of the meteorological fields potentially producing spurious vertical velocities.

4.3.3 Validation of CALMET Wind Field

CH2M HILL used the CALDESK (program to display data and results) data display and analysis system (v2.97, Enviromodeling Ltd.) to view plots of wind vectors and other meteorological parameters to evaluate the CALMET wind fields. CH2M HILL observed weather conditions, as depicted in surface and upper-air weather maps from the National Oceanic and Atmospheric Administration Central Library U.S. Daily Weather Maps Project (http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html), to compare to the CALDESK displays.

4.4 CALPUFF Methodology

4.4.1 CALPUFF Modeling

CH2M HILL ran the CALPUFF model with the meteorological output from CALMET over the CALPUFF modeling domain (Figure 4-1). The CALPUFF model was used to predict visibility impacts for the pre-control (baseline) scenario for comparison to the predicted impacts for post-control scenarios.

Background Ozone and Ammonia

Hourly values of background ozone concentrations were used by CALPUFF for the calculation of SO_2 and NO_x transformation with the MESOPUFF II chemical transformation scheme. CH2M HILL used the hourly ozone data generated for the WRAP BART analysis for 2001, 2002, and 2003.

For periods of missing hourly ozone data, the chemical transformation relied on a monthly default value of 80 parts per billion. Background ammonia was set to 1 part per billion as recommended in WRAP (2006).

Stack Parameters

The baseline stack parameters for the baseline and post-control scenarios were supplied by AEPCO staff. The parameters used in the WRAP analysis appeared to be related to natural gas combustion so it was necessary to replace these with more applicable values. The same stack data were used for all scenarios since none of the emission controls related to these scenarios would significantly affect the exhaust exit flows or temperatures.

Pre-Control Emission Rates

Pre-control emission rates reflect normal maximum capacity 24-hour emissions that may occur under the source's current permit. The emission rates reflect actual emissions under normal operating conditions. As described by the EPA in the Regional Haze Regulations and Guidelines for BART Determinations; Final Rule (40 CFR Part 51; July 6, 2005, pg 39129):

> *"The emissions estimates used in the models are intended to reflect steady-state operating conditions during periods of high-capacity utilization. We do not generally recommend that emissions reflecting periods of start-up, shutdown, and malfunction be used..."*

CH2M HILL used available CEM data to determine the baseline emission rates. Data reflect operations from 2001 through 2006.

Emissions were modeled for the following species:

- Sulfur dioxide (SO_2)
- Oxides of nitrogen (NO_x)
- Coarse particulate (diameter greater than $PM_{2.5}$ and less than or equal to PM_{10})
- Fine particulate (diameter less than or equal to $PM_{2.5}$)
- Elemental carbon (EC)
- Organic aerosols (SOA)
- Sulfates (SO_4)

Post-control Emission Rates

Post-control emission rates reflected the effects of the emissions control scenario under consideration. Modeled pollutants were the same as listed for the pre-control scenario.

Modeling Process

The CALPUFF modeling for the control technology options followed this sequence:

- Model WRAP-RMC parameters to verify results
- Model pre-control (baseline) emissions
- Determine the degree of visibility improvement
- Model other control scenarios if applicable
- Determine the degree of visibility improvement
- Factor visibility results into BART five-step evaluation

4.4.2 Receptor Grids and Coordinate Conversion

The TRC COORDS program was used to convert the latitude/longitude coordinates to LCC coordinates for the meteorological stations and source locations. The USGS conversion program PROJ (version 4.4.6) was used to convert the National Park Service receptor location data from latitude/longitude to LCC map.

For the Class I areas that are within 300 kilometers of the Apache Power Plant, discrete receptors for the CALPUFF modeling were taken from the National Park Service database for Class I area modeling receptors. The entire area of each Class I area that is within or intersects the 300-kilometer circle (Figure 4-1) were included in the modeling analysis. The following lists the Class I areas that were modeled for the Apache facility:

- Chiricahua WA and National Monument (NM)
- Galiuro WA
- Gila WA
- Mazatzal WA
- Mount Baldy WA
- Pine Mountain WA
- Saguaro NP
- Sierra Ancha WA
- Superstition WA

4.5 Visibility Post-processing

4.5.1 CALPOST

The CALPOST processor was used to determine 24-hour average visibility results. Output is specified in deciview (dV) units.

Calculations of light extinction were made for each pollutant modeled. The sum of all extinction values was used to calculate the delta-dV (Δdv) change relative to natural background. The following default extinction coefficients for each species were used:

- Ammonium sulfate 3.0
- Ammonium nitrate 3.0
- PM coarse (PM_{10}) 0.6
- PM fine ($PM_{2.5}$) 1.0
- Organic carbon 4.0
- Elemental carbon 10.0

CALPOST Visibility Method 6 (MVISBK=6) was used for the determination of visibility impacts. Monthly average relative humidity factors (*f*[RH]) were used in the light extinction calculations to account for the hygroscopic characteristic of sulfate and nitrate particles. Monthly *f*(RH) values, from the WRAP_RMC BART modeling, were used in CALPOST for the particular Class I area being modeled.

The natural background conditions used in the post-processing to determine the change in visual range background—or dV—represent the average natural background concentration for western Class I areas.

Table 4-2 lists the annual average species concentrations from the EPA Guidance.

TABLE 4-2
Average Natural Levels of Aerosol Components

Aerosol Component	Average Natural Concentration ($\mu g/m^3$) for Western Class I Areas
Ammonium Sulfate	0.12
Ammonium Nitrate	0.10
Organic Carbon	0.47
Elemental Carbon	0.02
Soil	0.50
Coarse Mass	3.0

NOTE:
Taken from Table 2-1 of Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule. EPA-454/B-03-005, September 2003.

4.6 Results

Input and output files for the CALMET/CALPUFF modeling and post-processing will be provided in electronic format to the Arizona Department of Environmental Quality (ADEQ). Larger files, such as binary files generated by CALMET, have not been included on the submitted disks, but any omitted files will be provided electronically upon request.

4.6.1 WRAP Verification Runs Results

Tables 4-3 and 4-4 present the results of WRAP-RMC model verification runs. The results show good correlation in estimated maximum ΔdV. Much of the difference between these values is probably attributed to the different alignment of the LCC map grids.

TABLE 4-3
Results from WRAP-RMC CALPUFF Modeling for ST3-3 (WRAP 2007)

Class I Area	Min Distance (kilometers)	Max Delta ΔdV	98th Percentile ΔdV	Days > 0.5 ΔdV	98th Percentile Δdv for Each Year			98th ΔdV 3-year Avg
					2001	2002	2003	
Chiricahua	45	3.56	1.96	291	1.93	1.86	2.07	1.95
Galiuro	53	3.06	1.35	141	1.35	1.16	1.67	1.39
Saguaro	57	2.25	1.37	152	1.44	1.25	1.31	1.33
Gila	167	1.00	0.60	31	0.62	0.73	0.47	0.61
Superstition	183	2.66	0.61	41	0.55	0.61	0.76	0.64
Mt. Baldy	207	1.27	0.29	9	0.26	0.34	0.29	0.30
Sierra Ancha	208	2.05	0.43	17	0.42	0.43	0.41	0.42
Mazatzal	254	2.07	0.44	16	0.45	0.44	0.36	0.42
Pine Mt.	300	1.74	0.34	14	0.44	0.34	0.27	0.35

TABLE 4-4
Verification CALPUFF Modeling Results

Class I Area	Min Distance (kilometers)	Max Delta ΔdV	98th Percentile ΔdV	Days > 0.5 ΔdV	98th Percentile ΔdV for Each Year			98th ΔdV 3-year Avg
					2001	2002	2003	
Chiricahua	46	4.326	2.758	173	2.806	2.890	2.614	2.770
Galiuro	54	4.899	2.062	78	2.215	1.895	2.291	2.134
Saguaro	58	3.839	2.282	102	2.521	1.935	2.332	2.263
Gila	167	1.606	0.709	24	0.709	0.757	0.686	0.717
Superstition	183	3.166	0.995	33	1.006	0.861	1.092	0.986
Mt. Baldy	208	1.248	0.417	6	0.352	0.476	0.357	0.395
Sierra Ancha	208	2.434	0.649	15	0.647	0.750	0.596	0.664
Mazatzal	255	2.516	0.605	11	0.634	0.574	0.491	0.566
Pine Mt.	301	2.065	0.483	8	0.536	0.558	0.362	0.485

4.6.2 BART Least-cost Analysis

The results and comparisons of the CALPUFF modeling for the baseline emission rates and those for the alternative emission control scenarios are provided in Section 5.

Section 5.0
Preliminary Assessment
and Recommendations

5.0 Preliminary Assessment and Recommendations

5.1 Preliminary Recommended BART Controls

As a result of the completed technical and economic evaluations, and consideration of the modeling analysis for ST3, the preliminary recommended BART controls for NO_x, SO_2, and PM_{10} are as follows:

- The most cost-effective emissions control scenario for NO_x includes LNB with OFA. Precipitator upgrades for PM_{10} emission control is recommended.
- Upgrades to existing SO_2 scrubbers are also recommended. These upgrades are not evaluated in this section because the existing scrubbers are already operating near the presumptive BART levels and the upgrades will result in slight improvements.

The above NO_x recommendations were identified as Scenario 1 for the modeling analysis described in Section 4.0. Because AEPCO has yet to analyze what precipitator upgrades may be applicable to ST3 to improve PM_{10} performance, an emissions control scenario could not be developed for this option for the purposes of the modeling analysis. Therefore, control scenarios for this pollutant included a polishing fabric filter, as Scenario 6, and a replacement fabric filter as Scenario 7. The results from this analysis were then used to examine the validity of the preliminary BART recommendation. Visibility improvements for all emission control scenarios were analyzed, and the results are compared below, using a least-cost envelope analysis, as outlined in the draft EPA *New Source Review Workshop Manual* (1990).

5.2 Analysis Baseline and Scenarios

Table 5-1 compares the six emission control scenarios with expected emission levels.

TABLE 5-1
Emission Control Scenarios
ST3

Case	Description	Expected NO_x Emissions (lb/MMBtu)	Expected SO_2 Emissions (lb/MMBtu)	Expected PM_{10} Emissions (lb/MMBtu)
Baseline		0.430	0.151	0.045
Scenario 1	LNB with OFA	0.310	0.151	0.045
Scenario 2	ROFA	0.260	0.151	0.045
Scenario 3	ROFA with Rotamix	0.180	0.151	0.045
Scenario 4	LNB with OFA and SNCR	0.230	0.151	0.045
Scenario 5	LNB with OFA and SCR	0.070	0.151	0.045
Scenario 6	Polishing Fabric Filter	0.430	0.151	0.015
Scenario 7	Fabric Filter	0.430	0.151	0.015

The ranking of the different NO_x emission control scenarios based on annual costs, from lowest to highest cost, is presented on Table 5-2. The ranking of the particulate matter control scenarios based on annual costs, from lowest to highest cost, is presented in Table 5-3.

TABLE 5-2
Ranking of NO_x Control Scenarios by Cost
ST3

Rank	Scenario	Total Annual Cost
1	Scenario 1	$532,808
2	Scenario 2	$1,634,241
3	Scenario 4	$1,717,633
4	Scenario 3	$2,181,833
5	Scenario 5	$6,062,301

TABLE 5-3
Ranking of Particulate Matter Control Scenarios by Cost
ST3

Rank	Scenario	Total Annual Cost
1	Scenario 6	$2,192,357
2	Scenario 7	$2,868,595

The Baseline of this BART analysis was defined as the level of NO_x and PM_{10} emission control that would be representative of future operations without the additional cost and level of control associated with the scenarios. Figures 5-1 through 5-4 compare the modeled contribution to visual range reduction for each Class I area for the baseline and each NO_x emission control scenario. Figures 5-5 through 5-8 compare the modeled contribution to visual range reduction for each Class I area for the baseline and each particulate matter emission control scenario.

Of the nine Class I areas included in this analysis, results from the analysis for four of these areas are presented in this Chapter. These four areas were selected because they represented the maximum impacts shown on Tables 4-3 and 4-4. The results for all nine areas are presented in Appendix C. The four selected areas include:

- Chiricahua WA and NM
- Galiuro WA
- Saguaro NP
- Superstition WA

The facility impacts presented Table 4-4 demonstrates that predicted impacts at the above areas are more significant than those at the other Class I areas.

FIGURE 5-1
NO_x Control Scenarios—Maximum Contributions to Visual Range Reduction at Chiricahua WA and NM
ST3

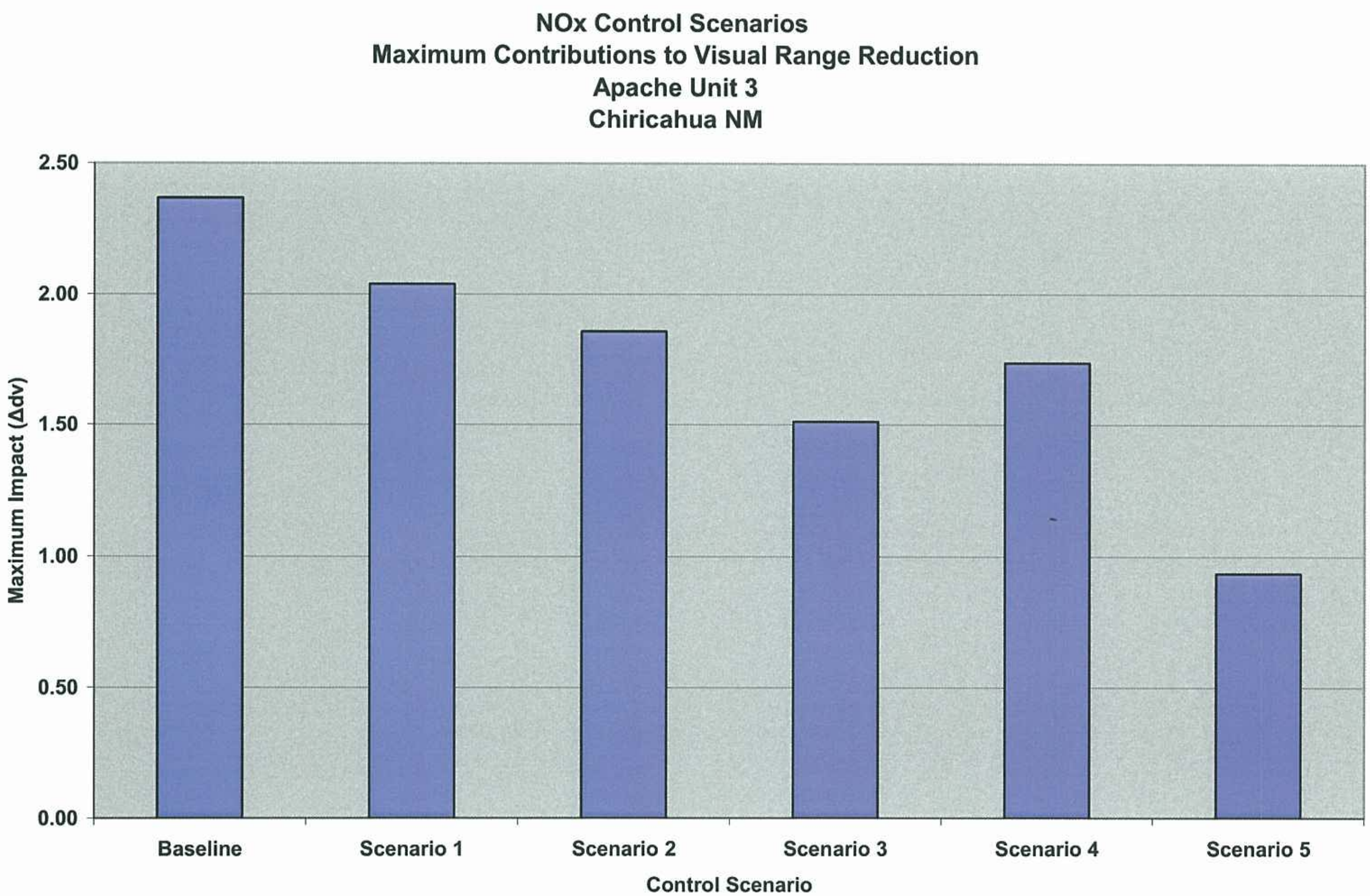


FIGURE 5-2
NO_x Control Scenarios—Maximum Contributions to Visual Range Reduction at Galiuro WA
ST3

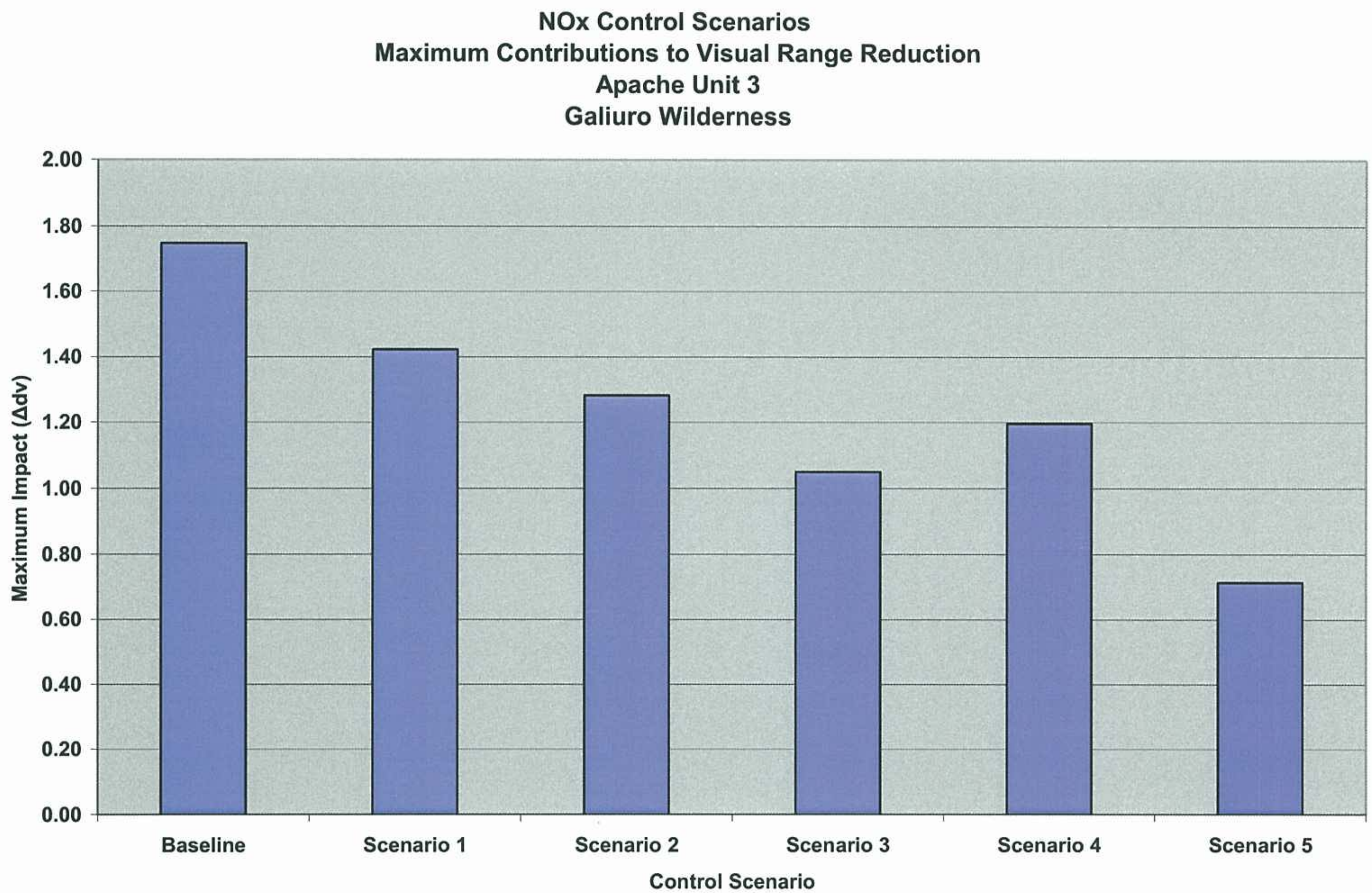


FIGURE 5-3
NO_x Control Scenarios—Maximum Contributions to Visual Range Reduction at Saguaro NP
ST3

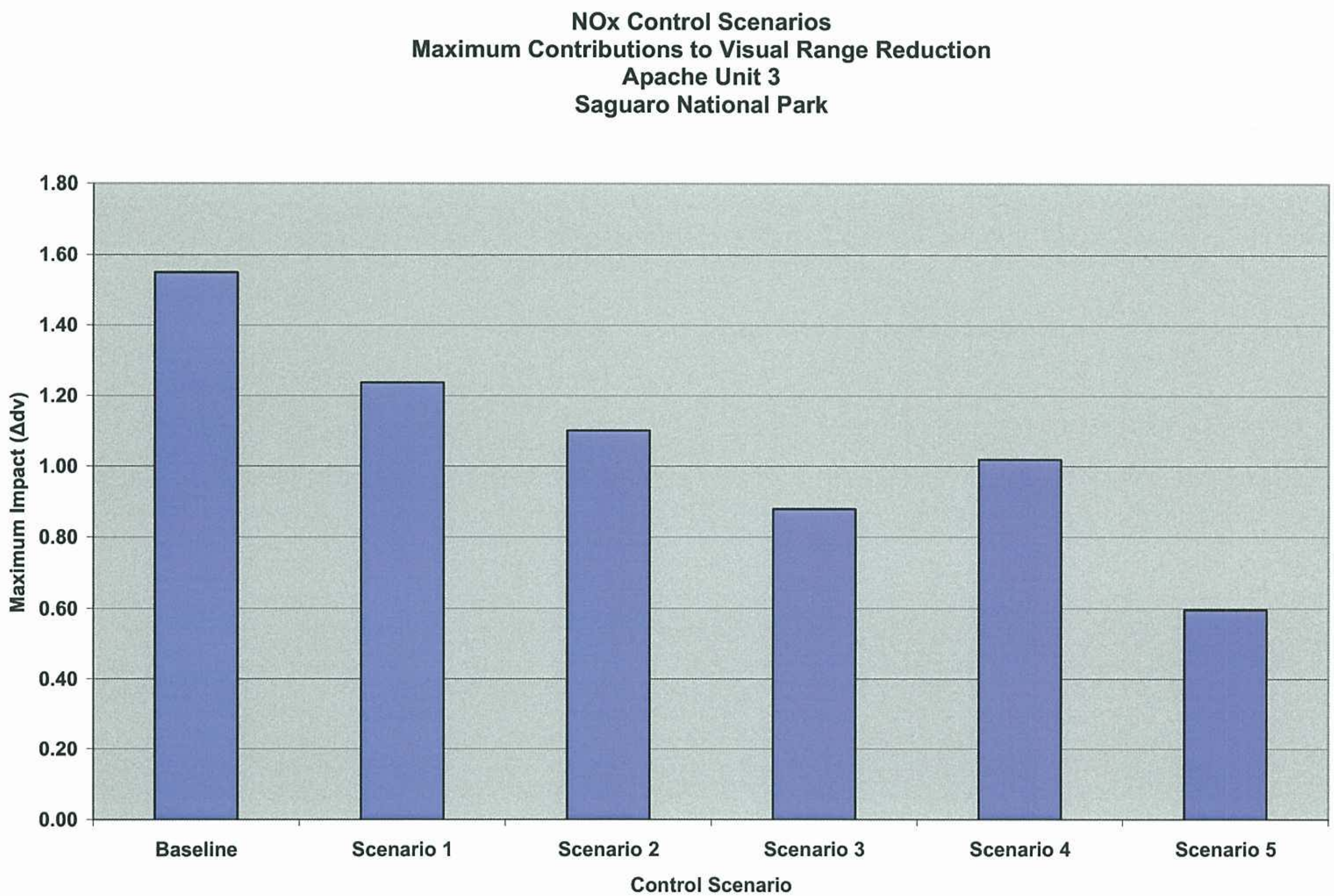


FIGURE 5-4
NO_x Control Scenarios—Maximum Contributions to Visual Range Reduction at Superstition WA
ST3

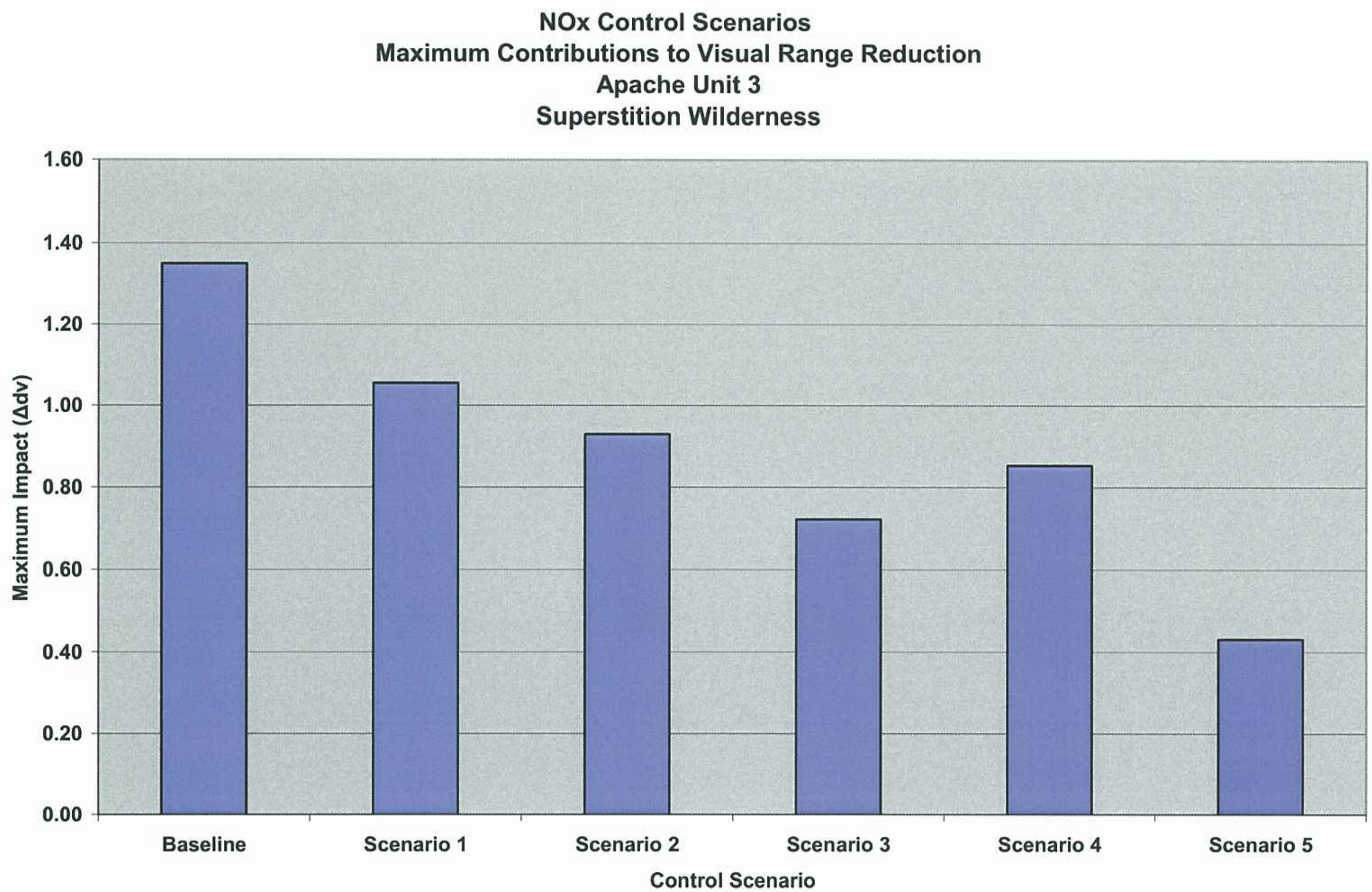


FIGURE 5-5
Particulate Matter Control Scenarios—Maximum Contributions to Visual Range Reduction at Chiricahua WA and NM
ST3

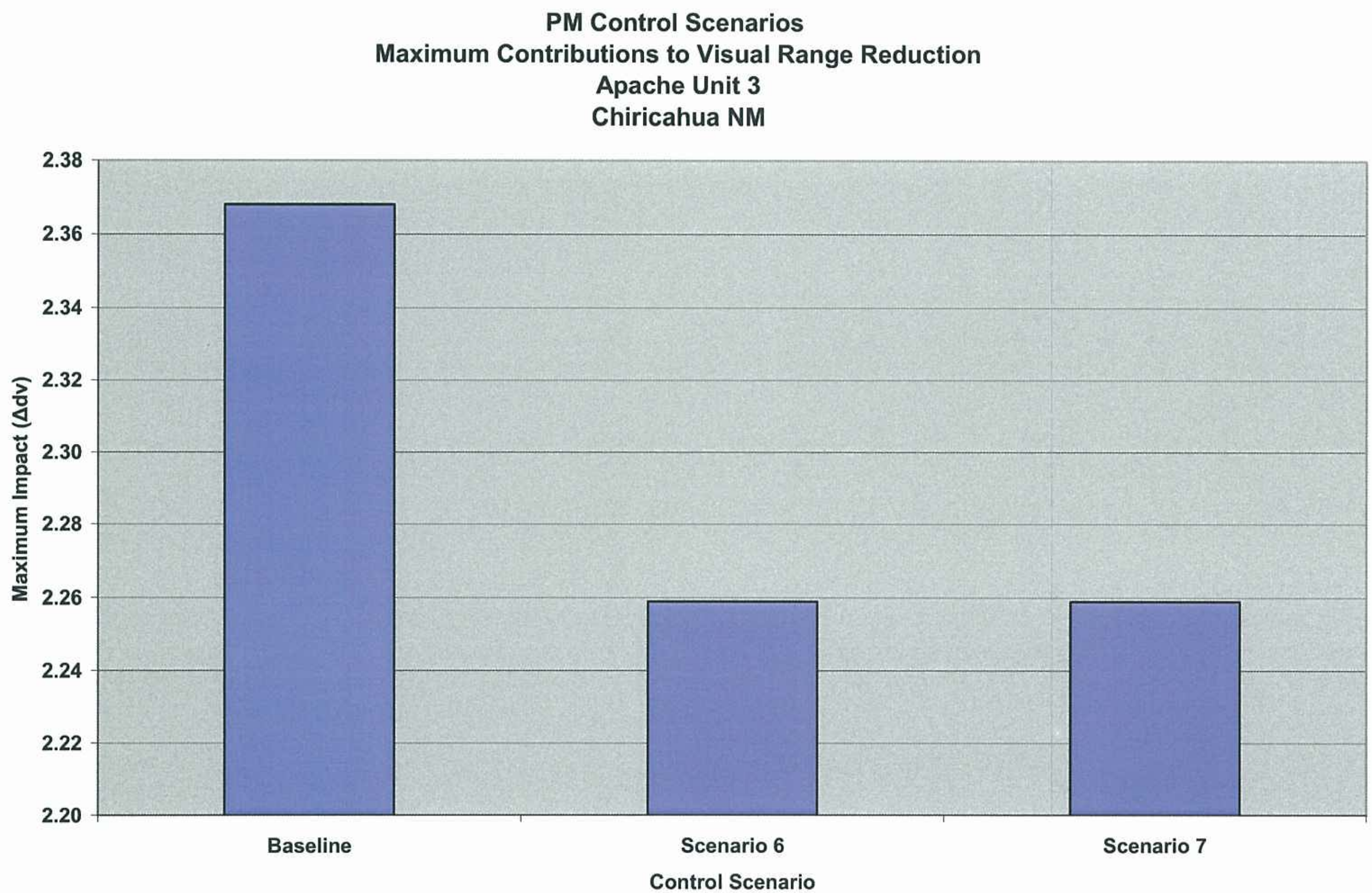


FIGURE 5-6
Particulate Matter Control Scenarios—Maximum Contributions to Visual Range Reduction at Galiuro WA
ST3

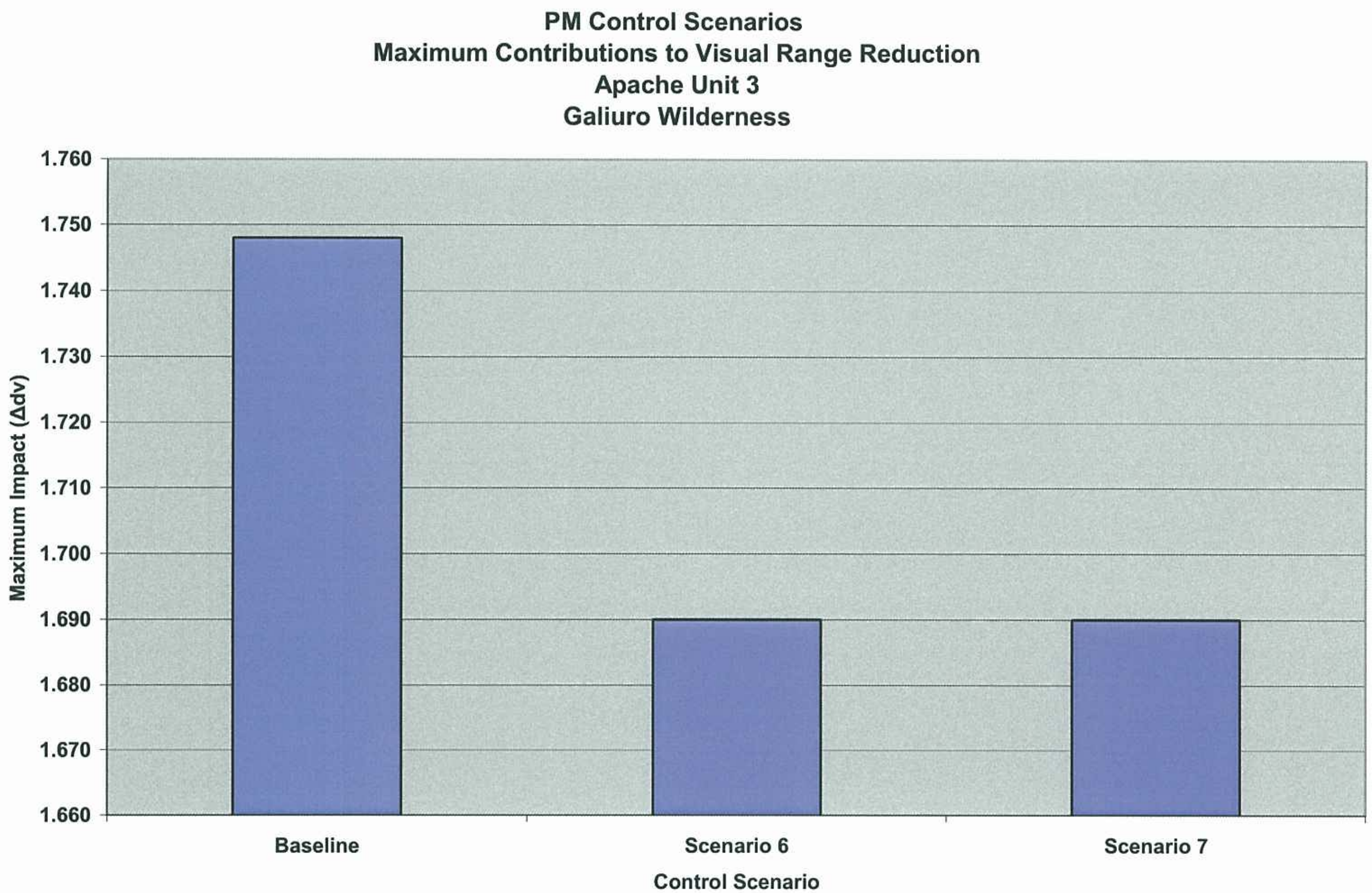


FIGURE 5-7
Particulate Matter Control Scenarios—Maximum Contributions to Visual Range Reduction at Saguaro NP
ST3

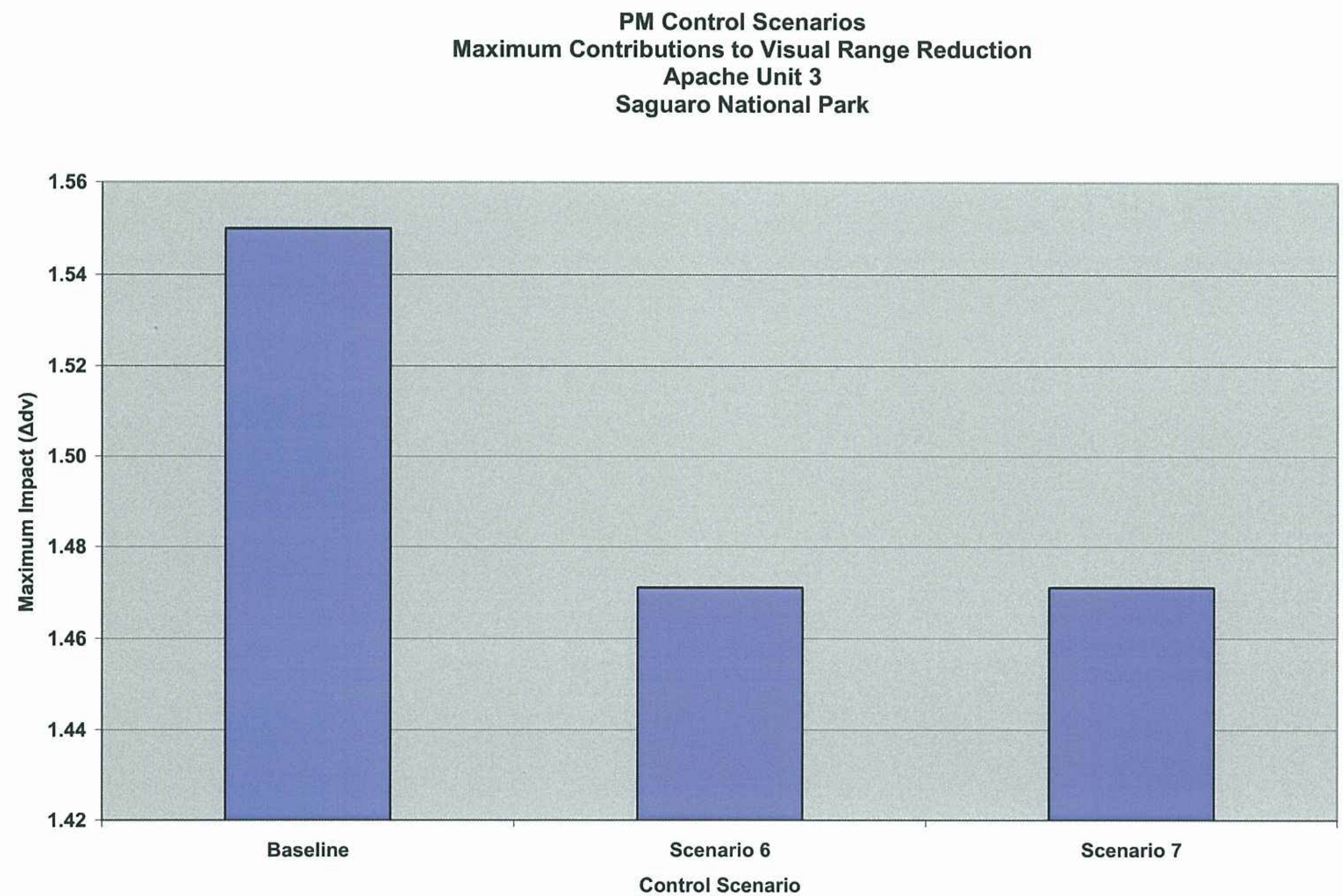
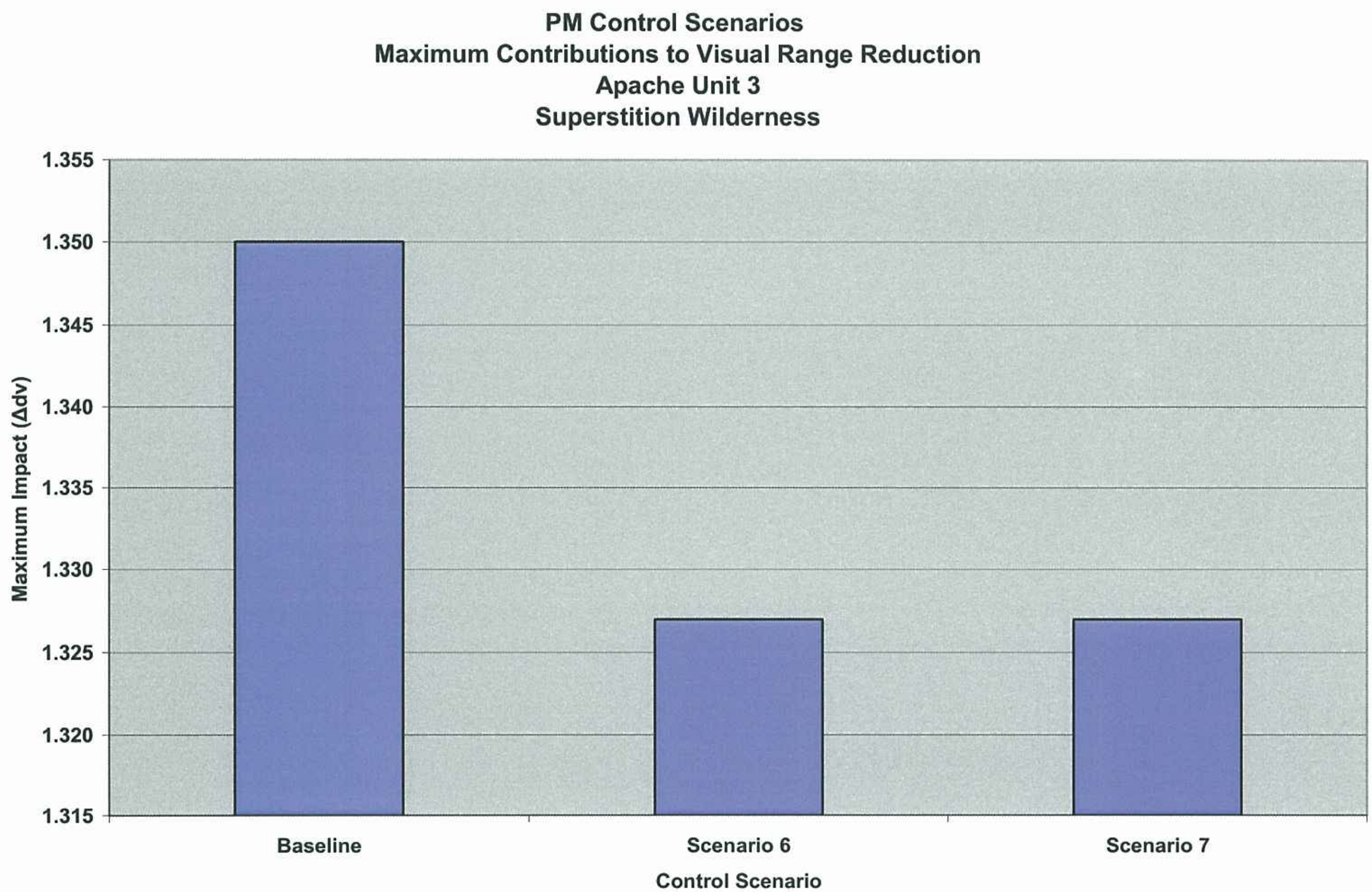


FIGURE 5-8
Particulate Matter Control Scenarios—Maximum Contributions to Visual Range Reduction at Superstition WA
ST3



5.3 Least-Cost Envelope Analysis

The total annualized cost, cost per ΔdV reduction, and cost per reduction in number of days above 0.5 ΔdV for each of the NO_x emission control scenarios and each of the selected Class I areas are listed in Tables 5-4 through 5-7. A comparison of the incremental costs between relevant scenarios is shown in Tables 5-8 through 5-11. The total annualized cost versus number of days above 0.5 ΔdV, and the total annualized cost versus 98th percentile ΔdV reduction are shown in Figures 5-9 through 5-16 for the four Class I areas.

5.3.1 Analysis Methodology

On page B-41 of the *New Source Review Workshop Manual* (EPA, 1990), the EPA states that,

> *"Incremental cost-effectiveness comparisons should focus on annualized cost and emission reduction differences between dominant alternatives. Dominant set of control alternatives are determined by generating what is called the envelope of least-cost alternatives. This is a graphical plot of total annualized costs for a total emissions reductions for all control alternatives identified in the BACT analysis..."*

An analysis of incremental cost effectiveness has been conducted. This analysis was performed in the following way. Control scenarios are selected from points that fall on the least-cost envelope curves (Figures 5-9 through 5-16). The incremental cost effectiveness data, expressed per day and per ΔdV, represents a comparison of the different scenarios, and is summarized in Tables 5-8 through 5-11 for each of the Class I areas. Then the most reasonable smooth curve of least-cost control option scenarios is plotted for each analysis. Figures 5-9 through 5-16 present the cost per ΔdV reduction for the Class I areas.

TABLE 5-4
NO_x Control Scenario Results for Chiricahua WA and NM
ST3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		45	0.000	0.000	0.000	0.000
1	LNB with OFA	35	0.206	0.533	0.053	2.586
2	ROFA	32	0.298	1.634	0.126	5.484
3	ROFA with Rotamix	20	0.436	2.182	0.087	5.004
4	LNB with OFA and SNCR	29	0.356	1.718	0.107	4.825
5	LNB with OFA and SCR	9	0.633	6.062	0.168	9.577

TABLE 5-5
NO_x Control Scenario Results for Galiuro WA
ST3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		16	0.000	0.000	0.000	0.000
1	LNB OFA	12	0.160	0.533	0.133	3.330
2	ROFA	9	0.230	1.634	0.233	7.105
3	ROFA with Rotamix	7	0.341	2.182	0.242	6.398
4	LNB with OFA and SNCR	9	0.273	1.718	0.245	6.292
5	LNB with OFA and SCR	1	0.461	6.062	0.404	13.150

TABLE 5-6
NO_x Control Scenario Results for Saguaro NP
ST3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		26	0.000	0.000	0.000	0.000
1	LNB with OFA	19	0.137	0.533	0.076	3.889
2	ROFA	17	0.211	1.634	0.182	7.745
3	ROFA with Rotamix	10	0.303	2.182	0.136	7.201
4	LNB with OFA and SNCR	14	0.248	1.718	0.143	6.926
5	LNB with OFA and SCR	4	0.450	6.062	0.276	13.472

TABLE 5-7
NO_x Control Scenario Results for Superstition WA
ST3

Scenario	Controls	Average Number of Days Above 0.5ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		2	0.000	0.000	0.000	0.000
1	LNB with OFA	2	0.054	0.533	NA	9.867
2	ROFA	2	0.074	1.634	NA	22.084
3	ROFA with Rotamix	2	0.102	2.182	NA	21.391
4	LNB with OFA and SNCR	2	0.086	1.718	NA	19.972
5	LNB with OFA and SCR	0	0.140	6.062	3.031	43.302

TABLE 5-8
Chiricahua WA and NM NO_x Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	10	0.206	0.533	0.053	2.586
Scenario 5 vs. Scenario 1	26	0.427	5.529	0.213	12.950

TABLE 5-9
Galiuro WA NO_x Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	4	0.160	0.533	0.133	3.330
Scenario 5 vs. Scenario 1	11	0.301	5.529	0.503	18.370

TABLE 5-10
Saguaro National Park NO_x Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	7	0.137	0.533	0.076	3.889
Scenario 5 vs. Scenario 1	15	0.313	5.529	0.369	17.666

TABLE 5-11
Superstition WA NO_x Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	0	0.054	0.533	NA	9.867
Scenario 5 vs. Scenario 1	2	0.086	5.529	2.765	64.296

FIGURE 5-9
NO_x Control Scenarios—Least-Cost Envelope Chiricahua WA and NM—Days Reduction
ST3

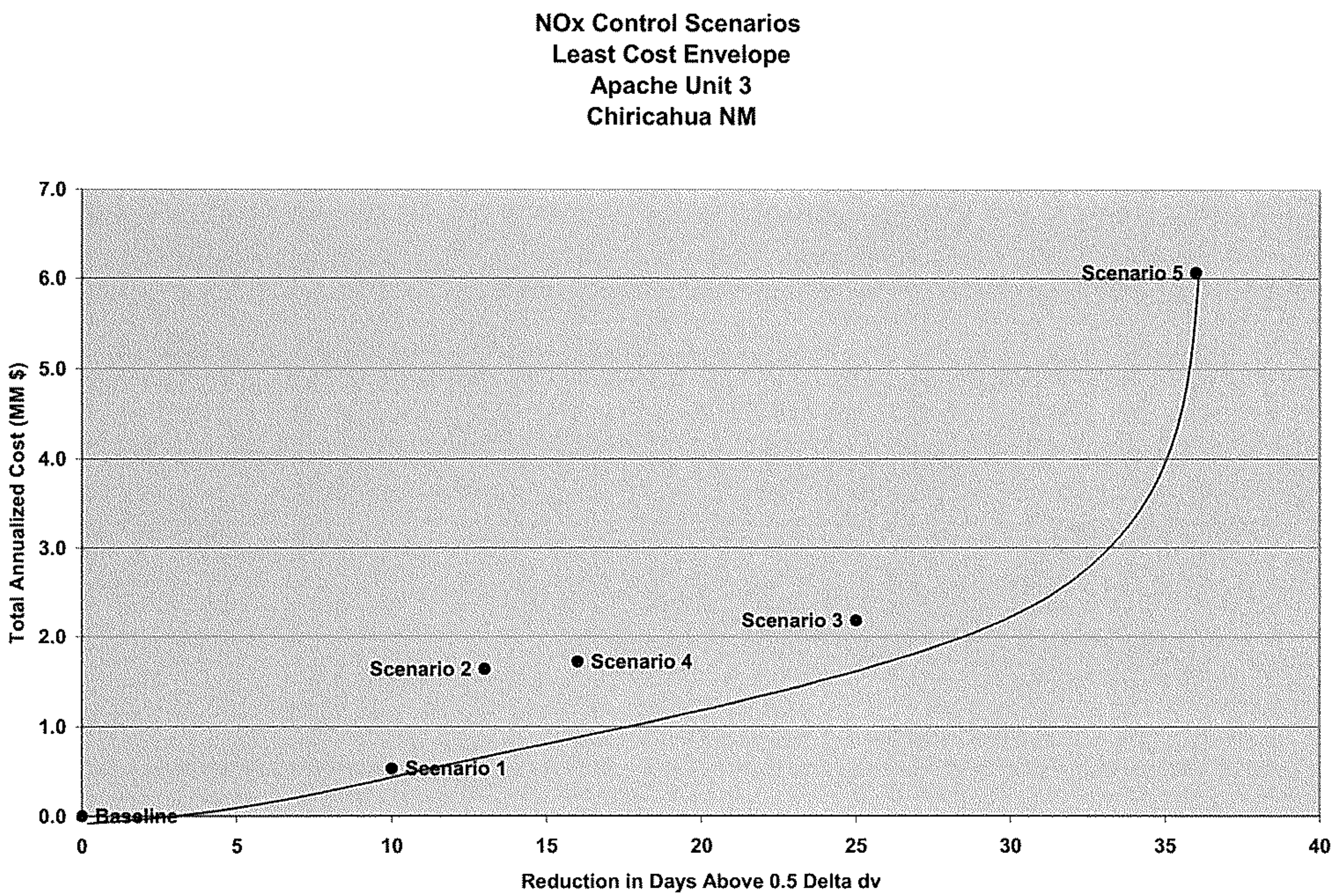


FIGURE 5-10
NO_x Control Scenarios—Least-Cost Envelope Chiricahua WA and NM—98th Percentile Reduction
ST3

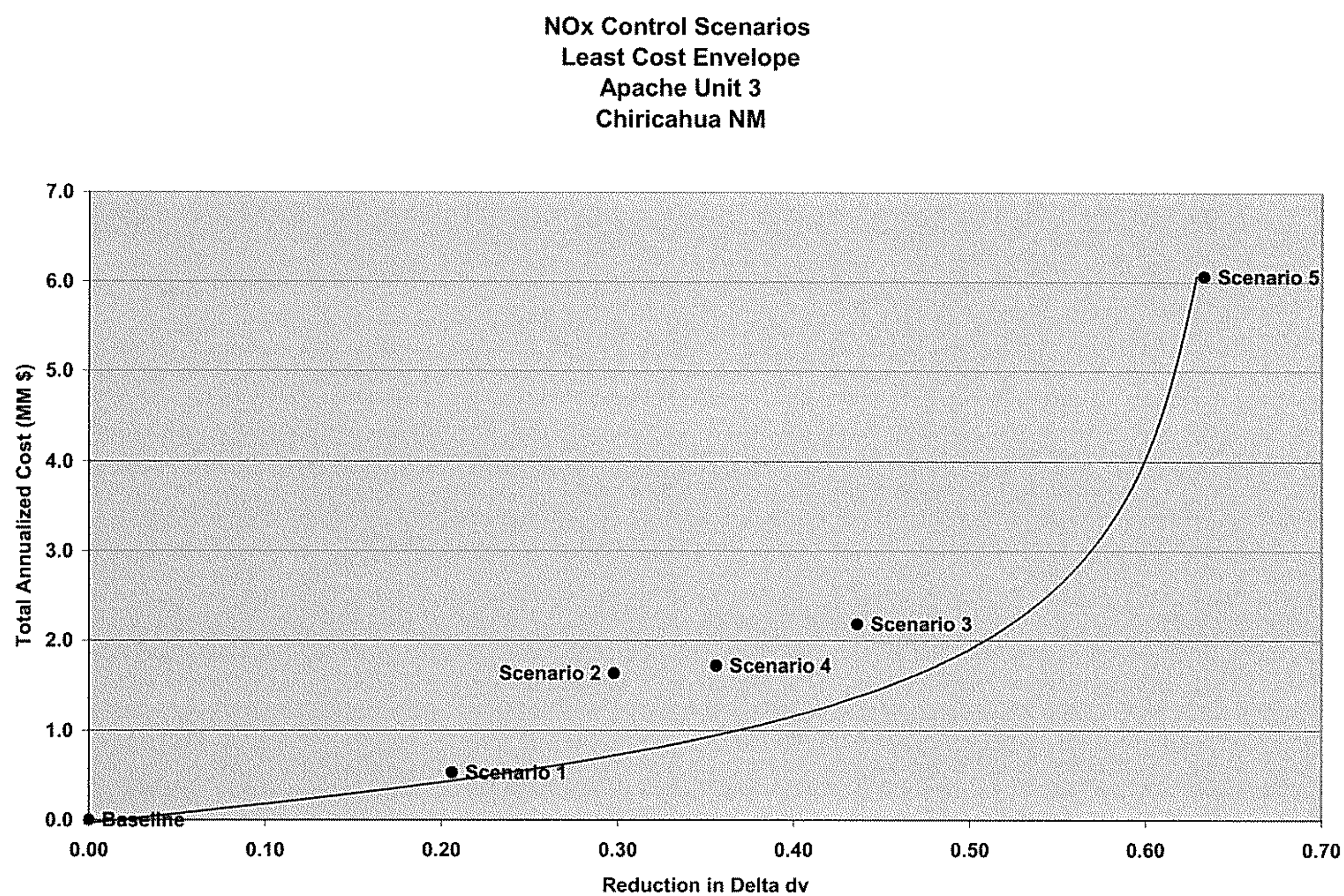


FIGURE 5-11
NO_x Control Scenarios—Least-Cost Envelope Galiuro WA—Days Reduction
ST3

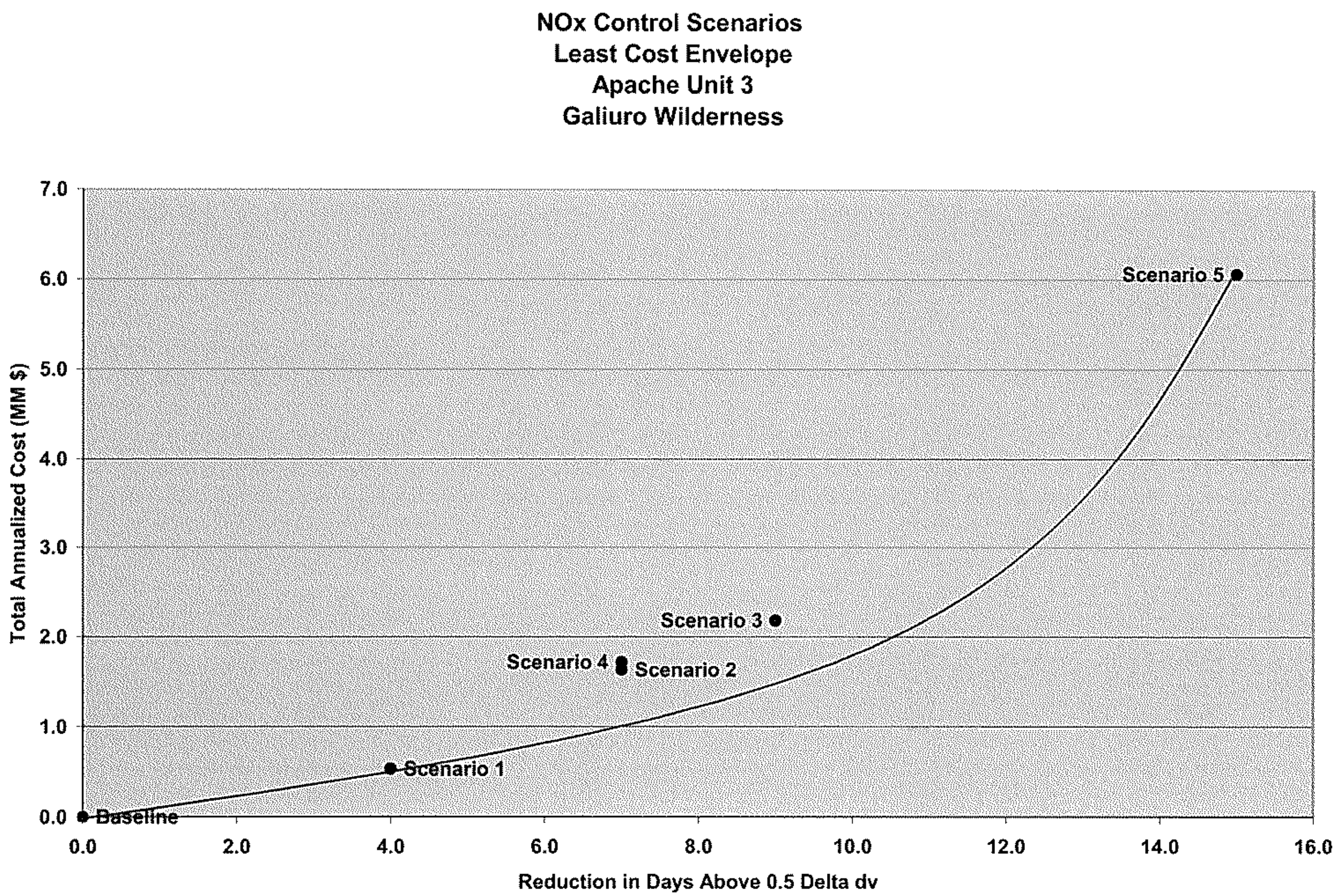


FIGURE 5-12
NO_x Control Scenarios—Least-Cost Envelope Galiuro WA—98th Percentile Reduction
ST3

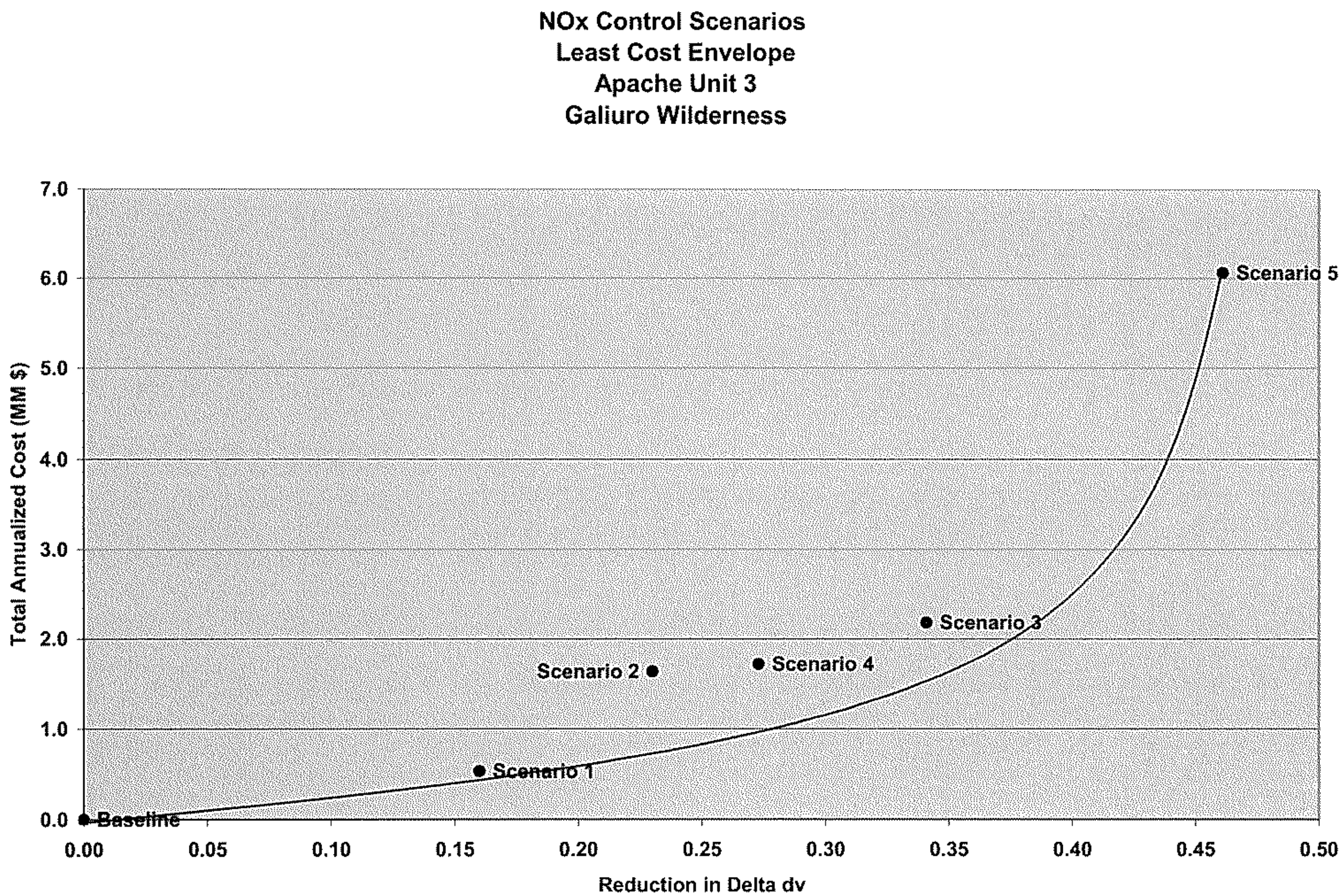


FIGURE 5-13
NO_x Control Scenarios—Least-Cost Envelope Saguaro NP—Days Reduction
ST3

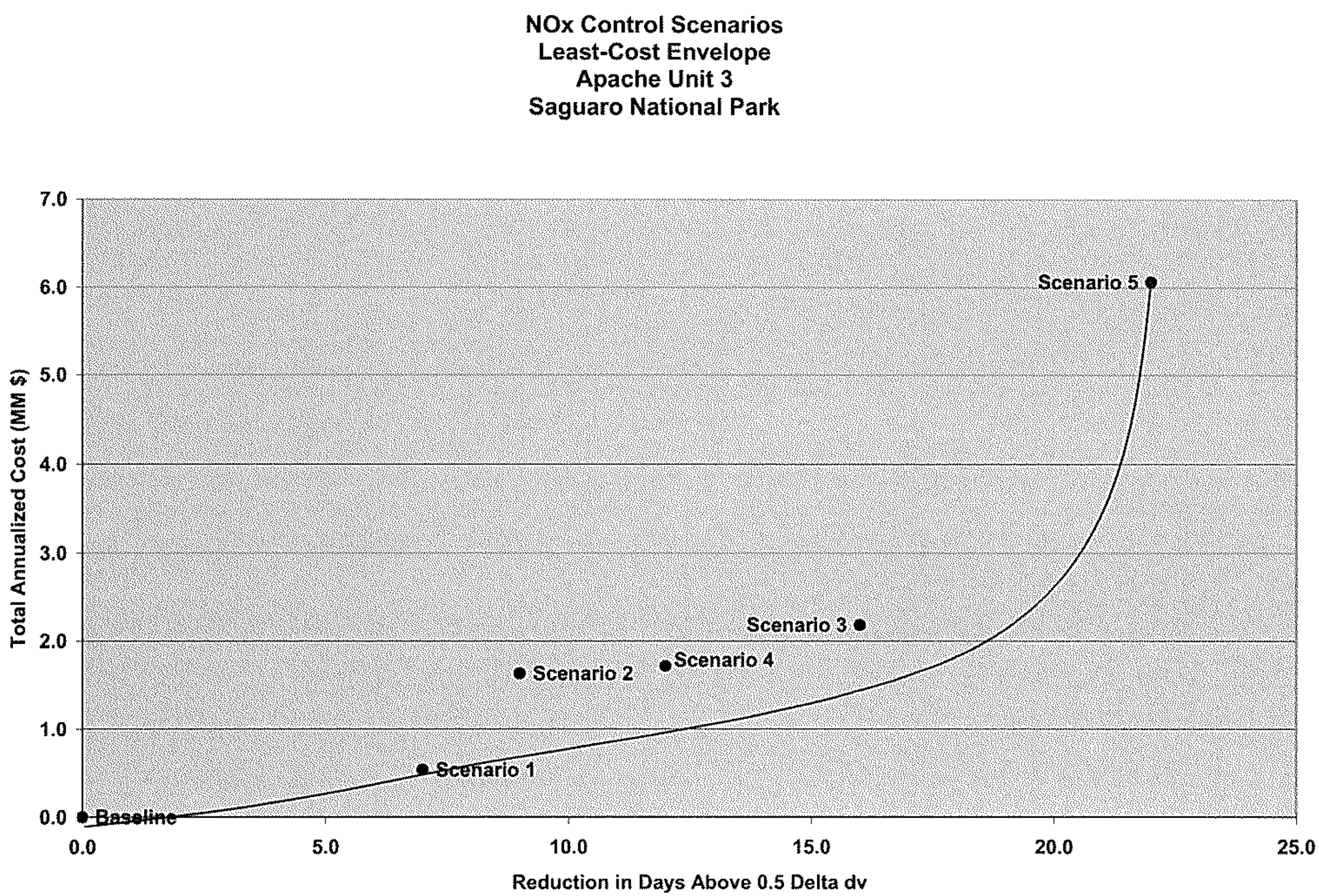


FIGURE 5-14
NO_x Control Scenarios—Least-Cost Envelope Saguaro NP—98th Percentile Reduction
ST3

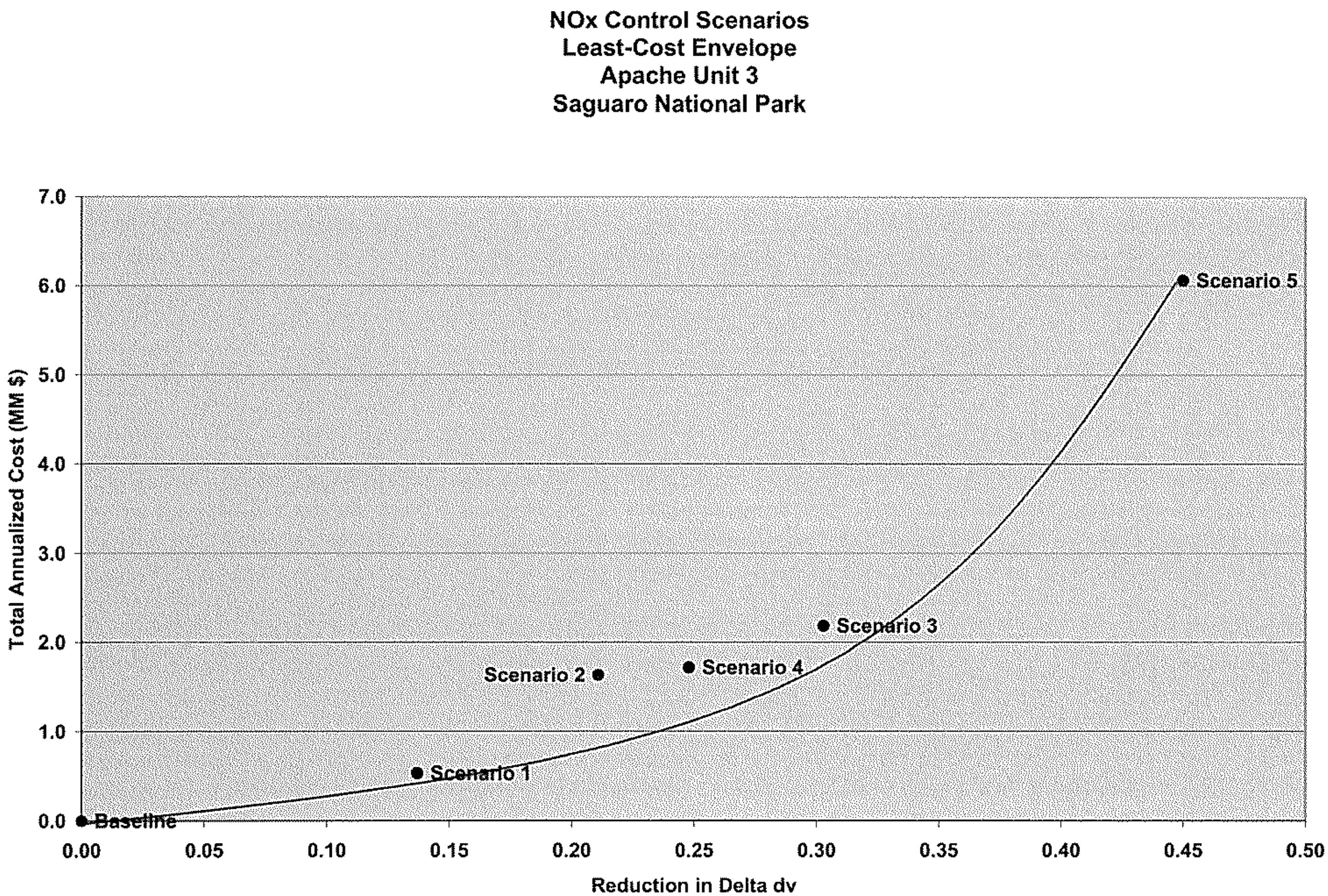


FIGURE 5-15
NO_x Control Scenarios—Least-Cost Envelope Superstition WA—Days Reduction
ST3

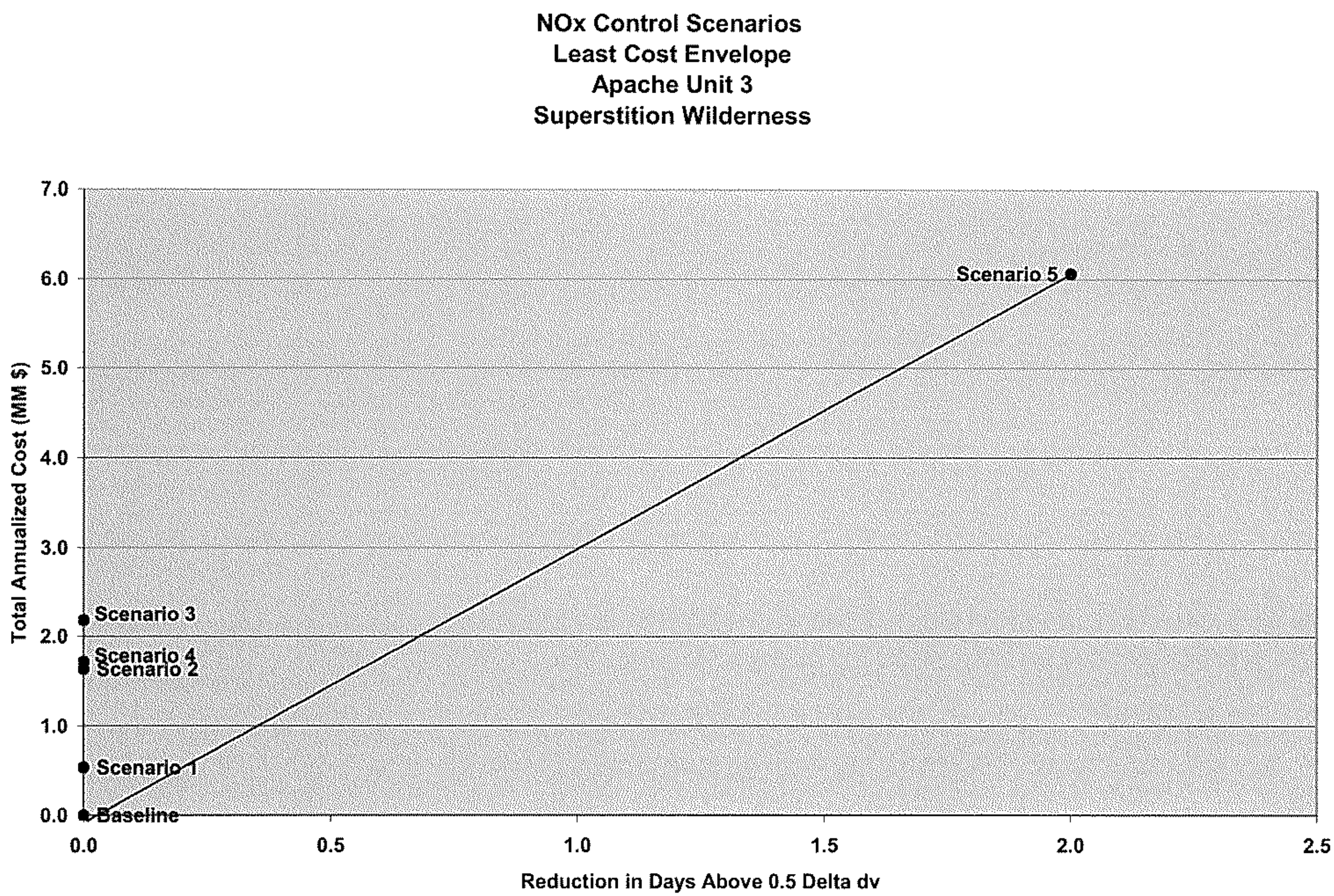


FIGURE 5-16
NO_x Control Scenarios—Least-Cost Envelope Superstition WA—98th Percentile Reduction
ST3

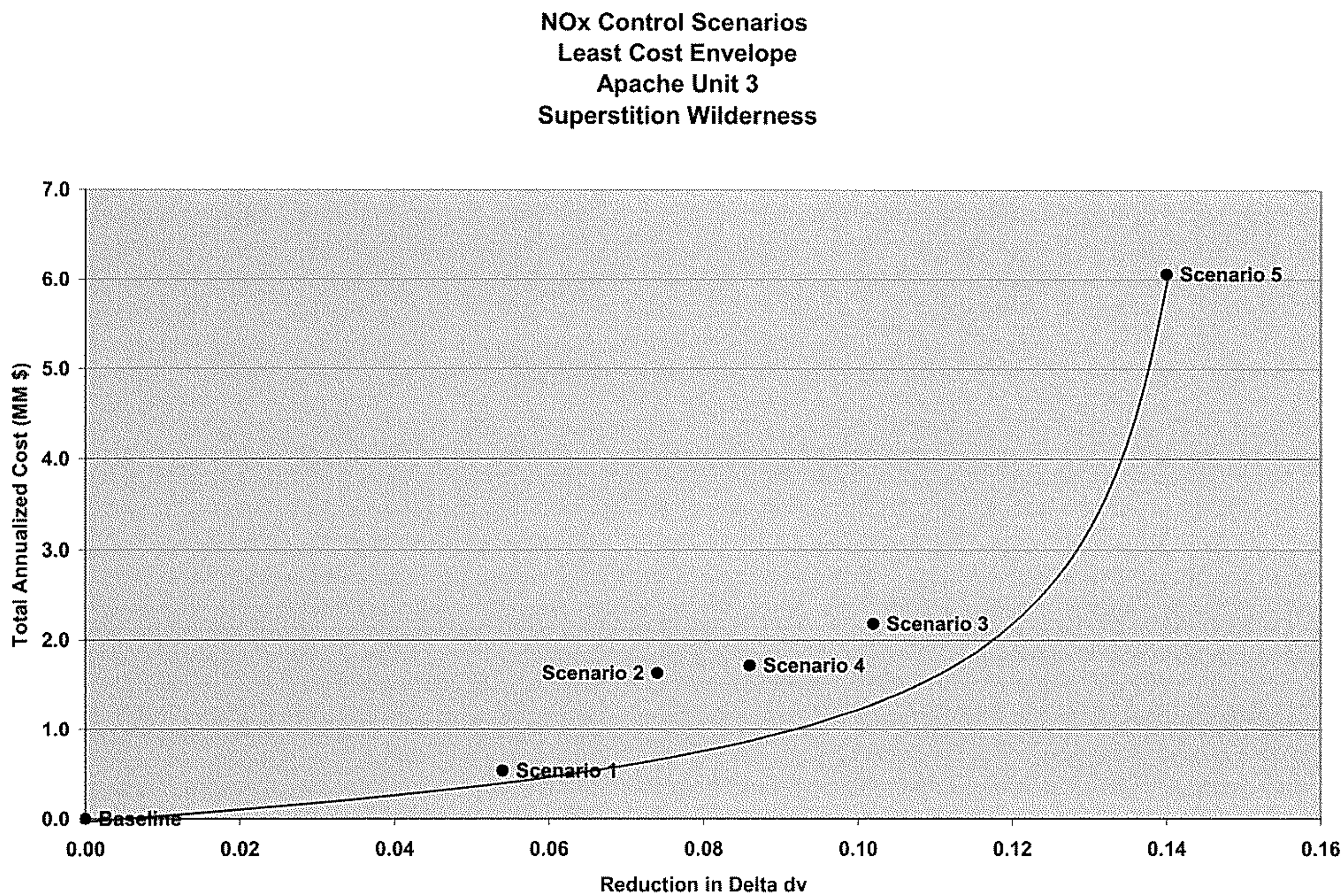


TABLE 5-12
Particulate Matter Control Scenario Results for Chiricahua WA and NM
ST3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/ Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		45	0.000	0.000	0.000	0.000
6	Polishing Fabric Filter	37	0.094	2.192	0.274	23.323
7	Fabric Filter	37	0.094	2.869	0.359	30.517

TABLE 5-13
Particulate Matter Control Scenario Results for Galiuro WA
ST3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/ Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		16	0.000	0.000	0.000	0.000
6	Polishing Fabric Filter	14	0.047	2.192	1.096	46.646
7	Fabric Filter	14	0.047	2.869	1.434	61.034

TABLE 5-14
Particulate Matter Control Scenario Results for Saguaro NP
ST3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/ Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		26	0.000	0.000	0.000	0.000
6	Polishing Fabric Filter	22	0.056	2.192	0.548	39.149
7	Fabric Filter	22	0.056	2.869	0.717	51.225

TABLE 5-15
Particulate Matter Control Scenario Results for Superstition WA
ST3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/ Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		2	0.000	0.000	0.000	0.000
6	Polishing Fabric Filter	2	0.007	2.192	NA	313.194
7	Fabric Filter	2	0.007	2.869	NA	409.799

TABLE 5-16
Chiricahua WA and NM Particulate Matter Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	8	0.094	2.192	0.274	23.323

TABLE 5-17
Galiuro WA Particulate Matter Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	2	0.047	2.192	1.096	46.646

TABLE 5-18
Saguaro NP Particulate Matter Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	4	0.056	2.192	0.548	39.149

TABLE 5-19
Superstition WA Particulate Matter Control Scenario Incremental Analysis Data
ST3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Day)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	0	0.007	2.192	NA	313.194

FIGURE 5-17
Particulate Matter Control Scenarios—Least-Cost Envelope Chiricahua WA and NM—Days Reduction
ST3

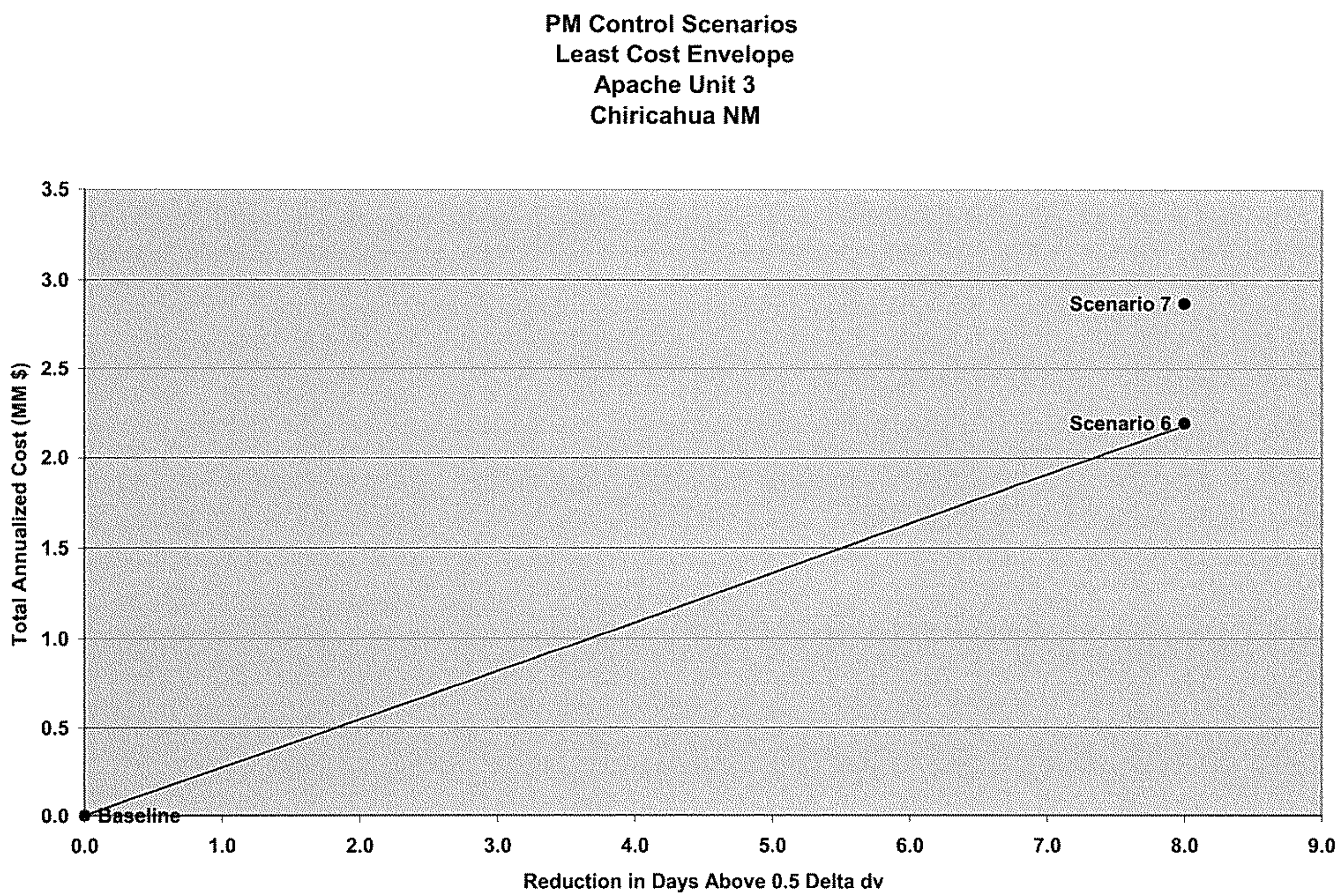


FIGURE 5-18
Particulate Matter Control Scenarios—Least-Cost Envelope Chiricahua WA and NM—98th Percentile Reduction
ST3

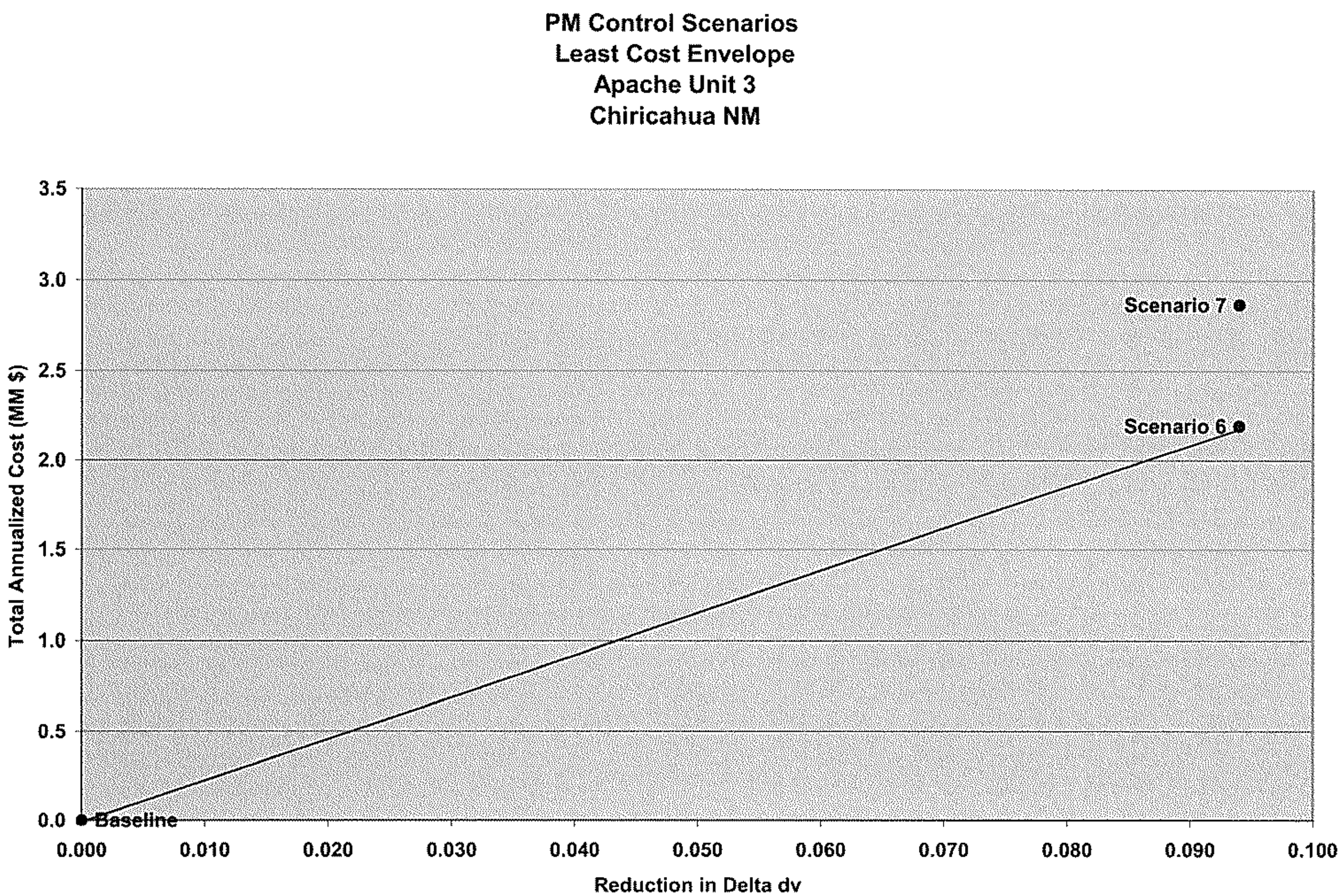


FIGURE 5-19
Particulate Matter Control Scenarios—Least-Cost Envelope Galiuro WA—Days Reduction
ST3

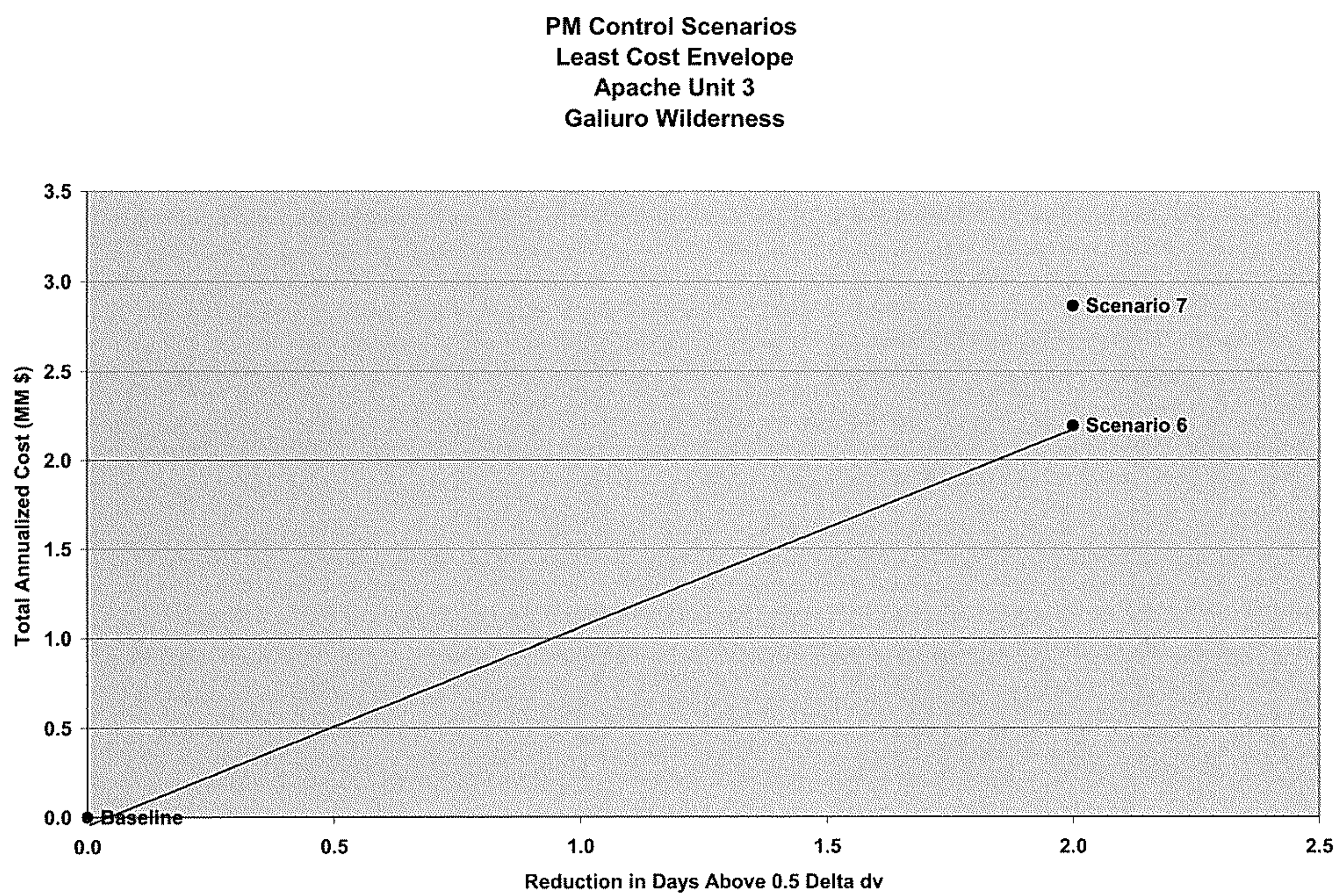


FIGURE 5-20
Particulate Matter Control Scenarios—Least-Cost Envelope Galiuro WA—98th Percentile Reduction
ST3

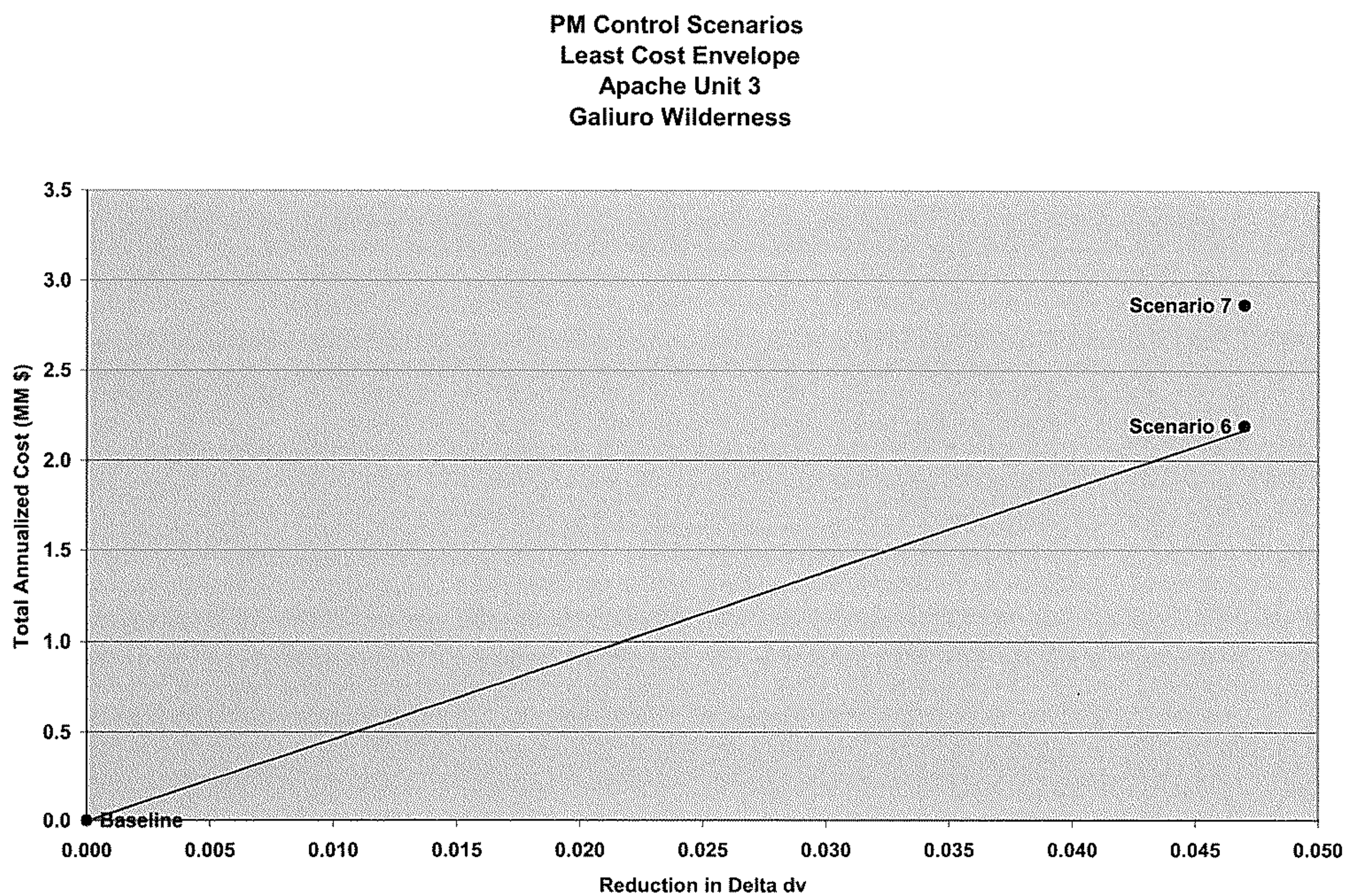


FIGURE 5-21
Particulate Matter Control Scenarios—Least-Cost Envelope Saguaro NP—Days Reduction
ST3

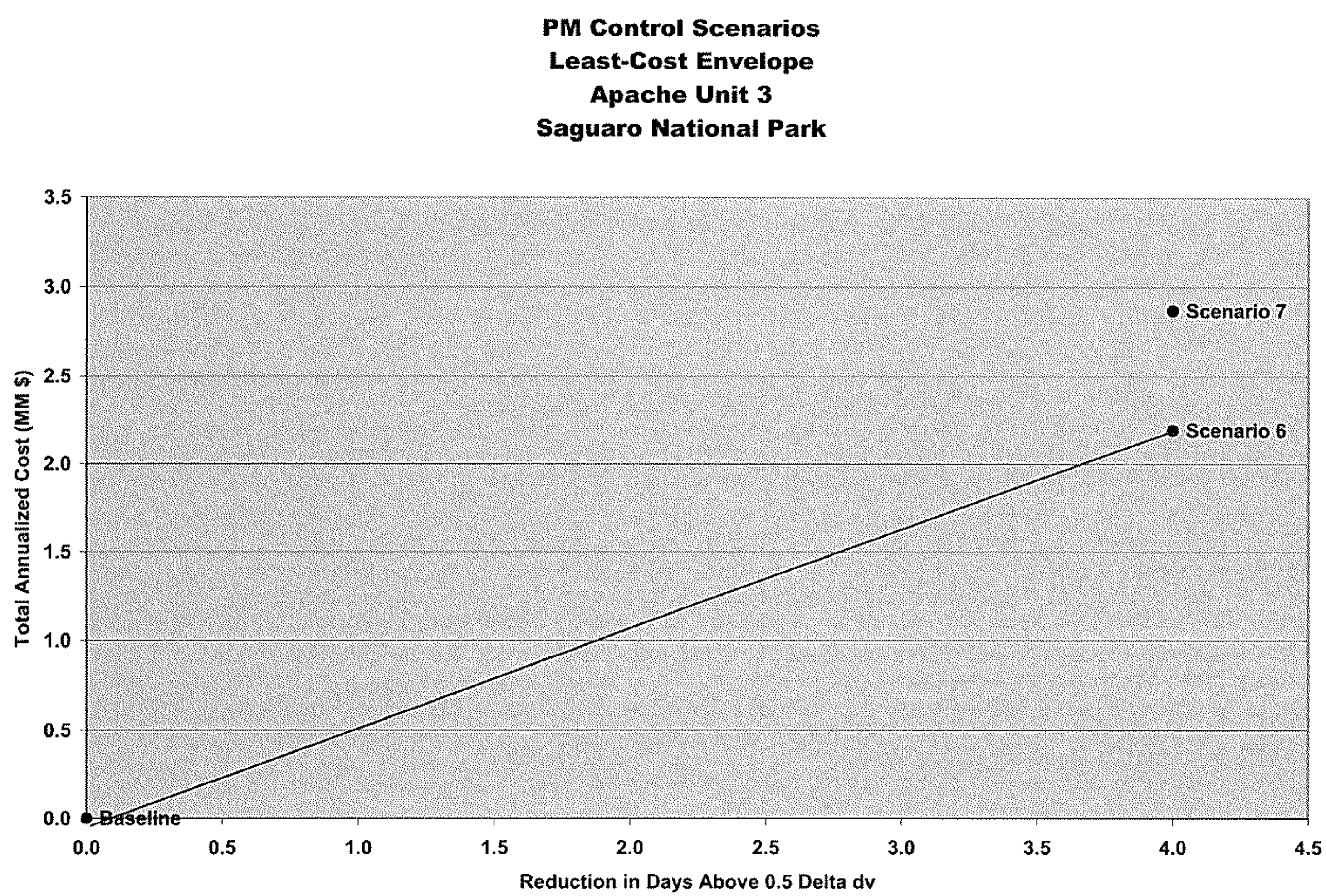


FIGURE 5-22
Particulate Matter Control Scenarios—Least-Cost Envelope Saguaro NP—98th Percentile Reduction
ST3

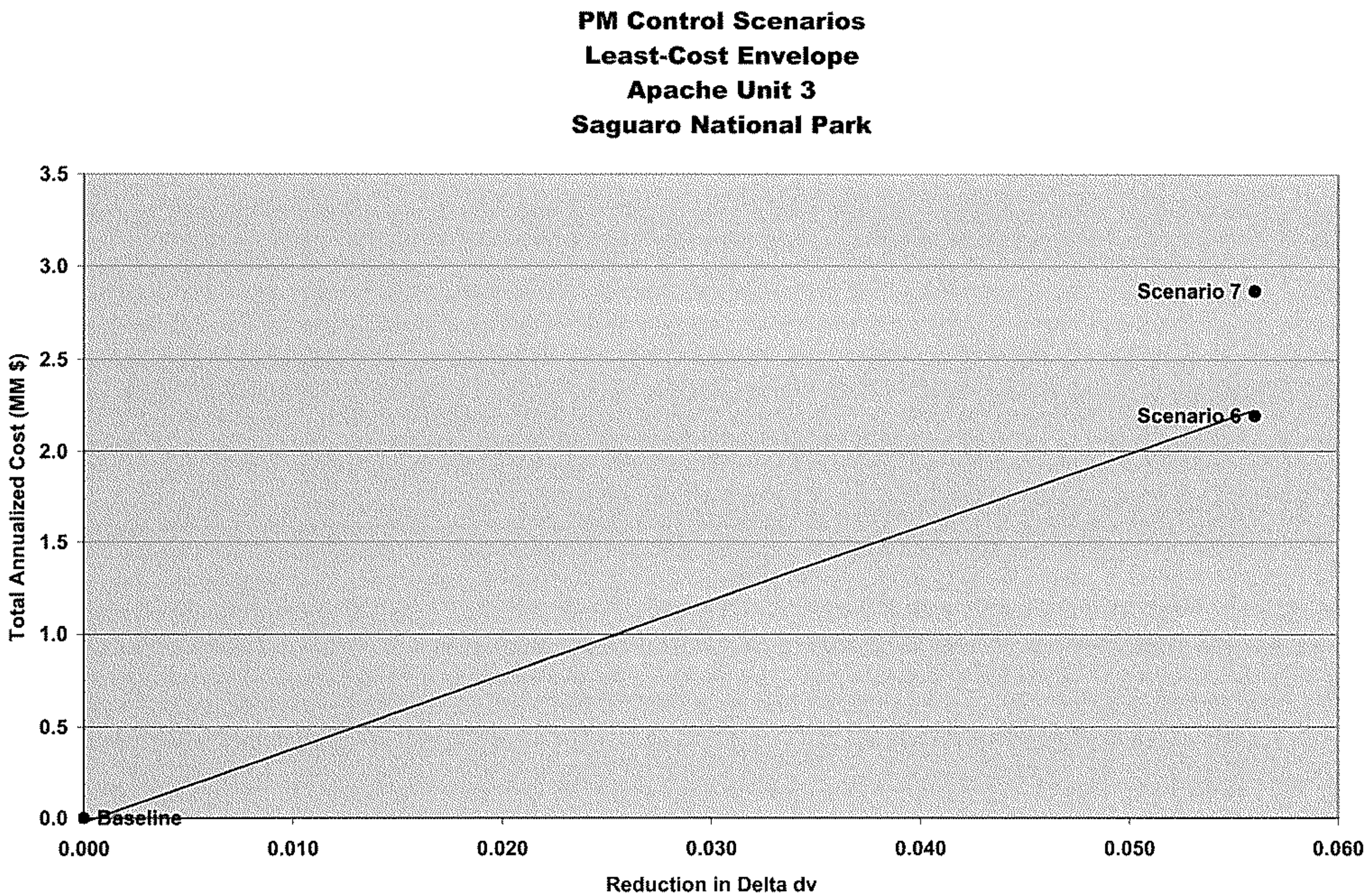


FIGURE 5-23
Particulate Matter Control Scenarios—Least-Cost Envelope Superstition WA—Days Reduction
ST3

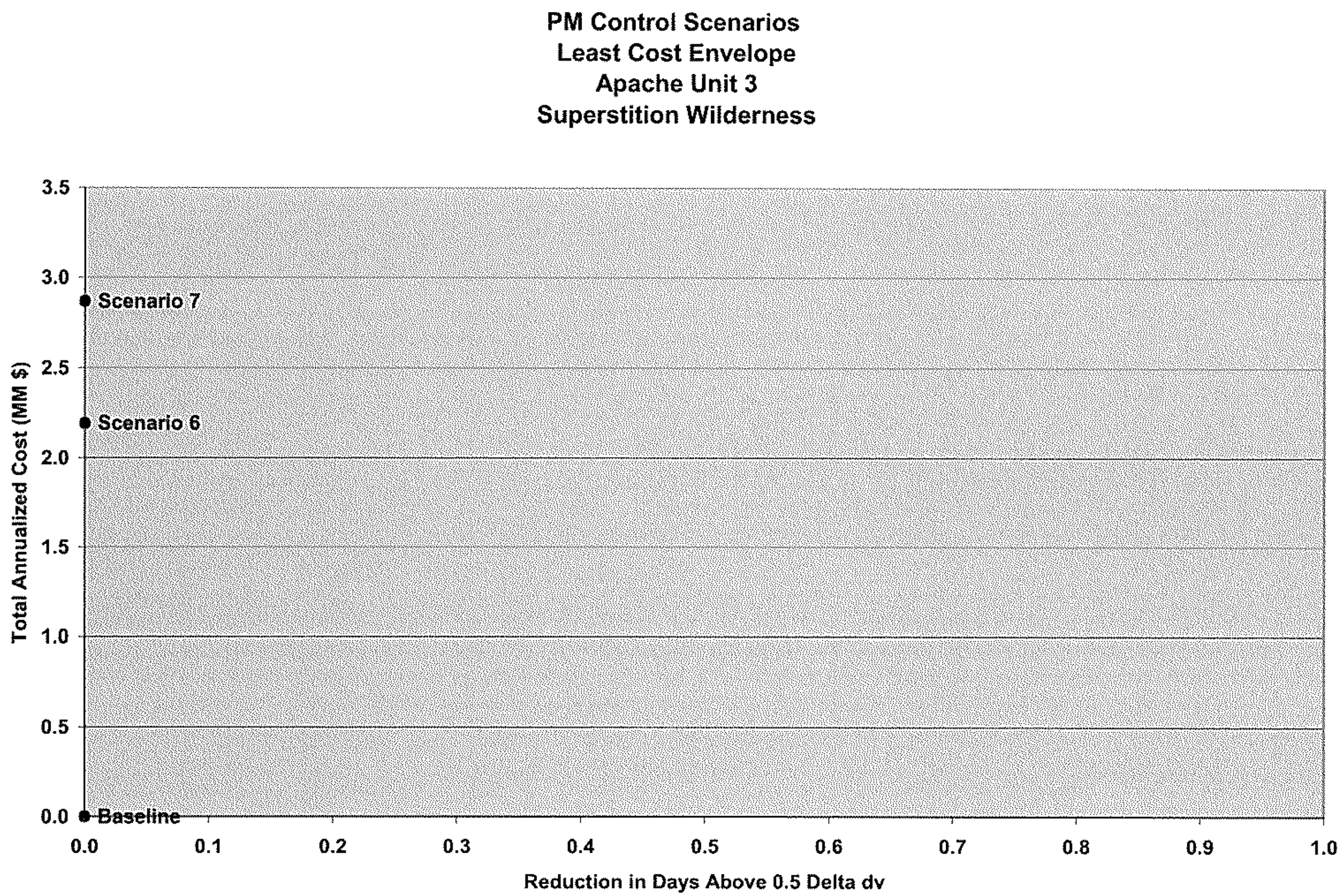
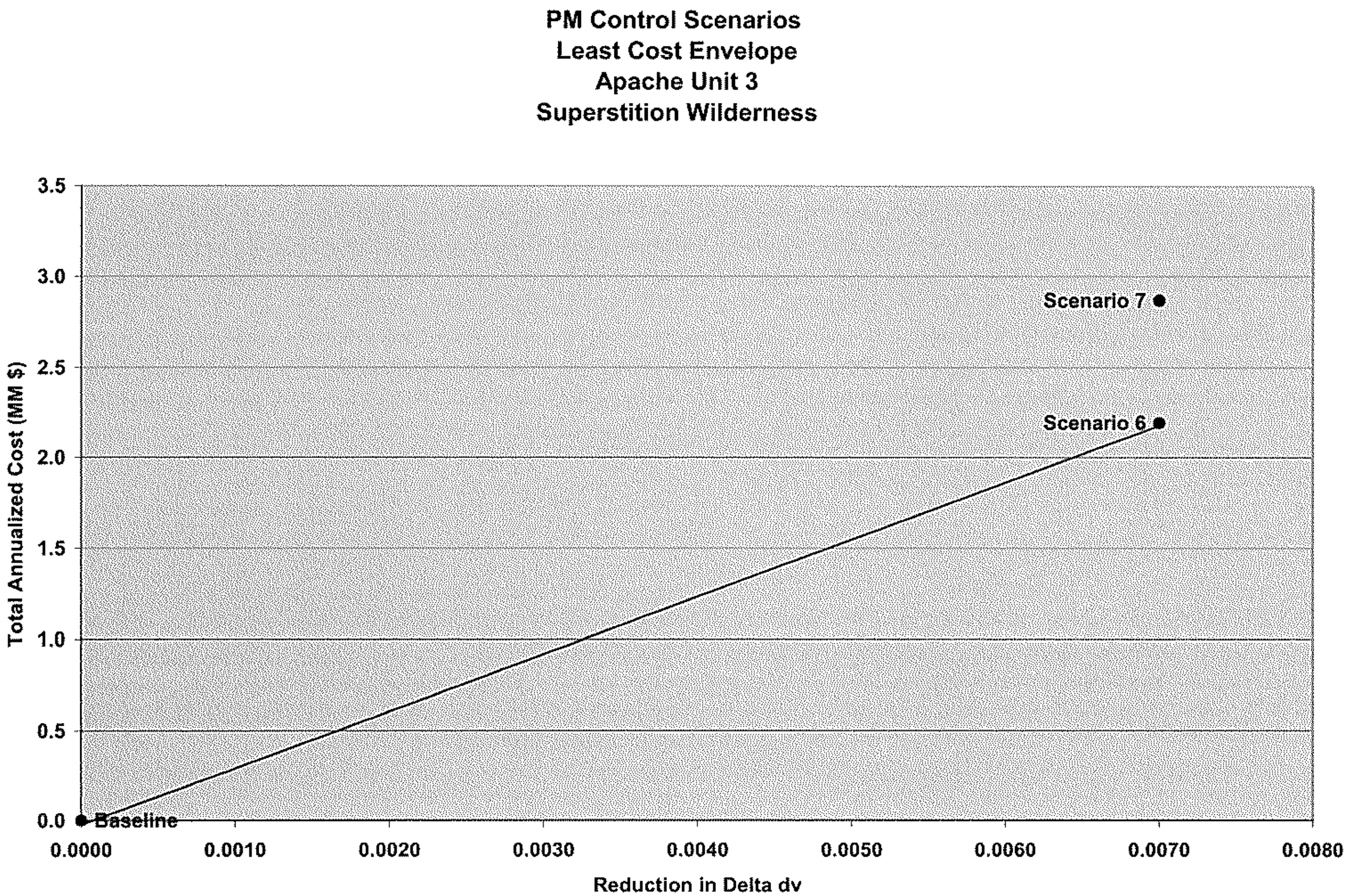


FIGURE 5-24
Particulate Matter Control Scenarios—Least-Cost Envelope Superstition WA—98th Percentile Reduction
ST3



5.3.2 Analysis Results

Results of the least-cost analysis for the various NO_x emission control scenarios, shown in Tables 5-4 through 5-11 and Figures 5-9 through 5-16, confirm the selection of Scenario 1 (LNB with OFA), based on incremental cost and visibility improvements. Scenario 5 (LNB with OFA and SCR), which also falls on the analysis envelope, has a significant increase in cost effectiveness. All other NO_x control scenarios are excluded on the basis of cost effectiveness.

Analysis of the NO_x results for the four Class I areas in Tables 5-4 through 5-11 and Figures 5-9 through 5-16 illustrates the conclusions stated above. For Chiricahua WA and NM, the incremental cost differential for Scenario 1 compared to Baseline is $2,586,000 per ΔdV. The incremental cost effectiveness between Scenario 5 and Scenario 1 shows a significant increase ($12,950,000 per ΔdV).

For Scenario 1 compared to the Baseline, the incremental cost for reduction of days with ΔdV values greater than 0.5 dV is reasonable at $53,000 per day. This incremental cost increases by more than four times ($213,000 per day) when comparing Scenario 5 to Scenario 1. Therefore Scenario 1 is selected as BART over Scenario 5.

Therefore, because of the significant improvements related to Scenario 1, Scenario 1 represents NO_x control BART for ST3.

The analysis of the PM_{10} results for the four Class I areas supports the preliminary recommendation that costs related to a polishing fabric filter or replacement fabric filter installation are not cost-effective related to expected visibility improvement. For Chiricahua WA and NM, the incremental cost differential for Scenario 6 (Polishing Fabric Filter) relative to the Baseline is $22,323,000 per ΔdV. Incremental cost for reduction of days with ΔdV values greater than 0.5 dV is much higher, at $274,000 per day, than any of the NO_x control scenarios analyzed.

5.4 Recommendations

5.4.1 NO_x Emission Control

Based on the analysis conducted, new LNB with OFA is recommended as BART for ST3, based on the projected significant reduction in NO_x emissions, reasonable control costs, and the advantages of no non-air quality environmental impacts.

5.4.2 SO_2 Emission Control

Based on the analysis conducted, scrubber upgrades are recommended for SO_2 emission control. AEPCO will define cost-effective options for obtaining additional SO_2 reductions from ST3.

5.4.3 PM_{10} Emission Control

After review of the high incremental costs and the high $/ton associated with a polishing fabric filter or a replacement fabric filter, precipitator upgrades are recommended as BART for PM_{10} emission control. AEPCO will define cost-effective options for obtaining additional PM_{10} reductions. If cost-effective enhancements can be defined and implemented, AEPCO would lower emissions between the boundaries represented by current baseline emission level (0.045 lb/MMBtu) and level represented by fabric filter control options (0.015 lb/MMBtu).

5.5 Just-Noticeable Differences in Atmospheric Haze

Studies have been conducted that demonstrate only dV differences of approximately 1.5 to 2.0 dV or more are perceptible by the human eye. Deciview changes of less than 1.5 cannot be distinguished by the average person. Therefore, the modeling analysis results indicate that only minimal, if any, observable visibility improvements at the Class I areas studied would be expected under any of the scenarios. Thus the results indicate that even though many millions of dollars will be spent, only minimal, if any, noticeable visibility improvements may result.

Finally, it should be noted that none of the data were corrected for natural obscuration where water in various forms (fog, clouds, snow, or rain) or other naturally caused aerosols obscure the atmosphere. During the period of 2001 through 2003, there were several mega-wildfires that lasted for many days and could have had a significant impact of background visibility in these Class I areas. If natural obscuration were to reduce the reduction in visibility impacts modeled for the ST3 facility, the effect would be to increase the costs per ΔdV reduction that are presented in this report.

Section 6.0
References

6.0 References

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Appendix A
Economic Analysis

APPENDIX A

Economic Analysis

ECONOMIC ANALYSIS SUMMARY

Apache Unit 3 (ST3) **Boiler Design:** **Dry Bottom Turbo-fired**

Parameter	Current Operation	NOx Control					PM Control	
		LNB w/OFA	ROFA	ROFA w/ Rotamix	LNB w/OFA & SNCR	LNB w/OFA & SCR	Polishing Fabric Filter	Fabric Filter
Case	1	2	3	4	5	6	7	8
NOx Emission Control System	OFA/UFA	LNB w/OFA	ROFA	ROFA w/ Rotamix	LNB w/OFA & SNCR	LNB w/OFA & SCR	OFA/UFA	OFA/UFA
SO2 Emission Control System	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber
PM Emission Control System	ESP	ESP	ESP	ESP	ESP	ESP	Filter	Fabric Filter
TOTAL INSTALLED CAPITAL COST ($)	**0**	**4,760,000**	**9,616,084**	**12,623,773**	**12,541,130**	**48,740,300**	**15,866,667**	**23,800,000**
FIRST YEAR O&M COST ($)								
Operating Labor ($)	0	0	0	0	0	0	0	0
Maintenance Material ($)	0	32,000	48,000	48,000	51,000	132,000	45,016	45,016
Maintenance Labor ($)	0	48,000	72,000	72,000	76,500	198,000	67,524	67,524
Administrative Labor ($)	0	0	0	0	0	0	0	0
TOTAL FIXED O&M COST	**0**	**80,000**	**120,000**	**120,000**	**127,500**	**330,000**	**112,540**	**112,540**
Makeup Water Cost	0	0	0	0	0	0	0	0
Reagent Cost	0	0	0	70,072	205,716	420,431	0	0
SCR Catalyst / FF Bag Cost	0	0	0	0	0	292,500	72,800	109,200
Waste Disposal Cost	0	0	0	0	0	0	0	0
Electric Power Cost	0	0	599,484	790,890	191,406	382,812	497,656	382,812
TOTAL VARIABLE O&M COST	**0**	**0**	**599,484**	**860,961**	**397,122**	**1,095,743**	**570,456**	**492,012**
TOTAL FIRST YEAR O&M COST	**0**	**80,000**	**719,484**	**980,961**	**524,622**	**1,425,743**	**682,996**	**604,552**
FIRST YEAR DEBT SERVICE ($)	0	452,808	914,757	1,200,872	1,193,010	4,636,559	1,509,361	2,264,042
TOTAL FIRST YEAR COST ($)	**0**	**532,808**	**1,634,241**	**2,181,833**	**1,717,633**	**6,062,301**	**2,192,357**	**2,868,595**
Power Consumption (MW)	**0.0**	**0.0**	**1.6**	**2.1**	**0.5**	**1.0**	**1.3**	**1.0**
Annual Power Usage (kW-Hr/Yr)	**0.0**	**0.0**	**12.0**	**15.8**	**3.8**	**7.7**	**10.0**	**7.7**
CONTROL COST ($/Ton Removed)								
NOx Removal Rate (%)	**0.0%**	**27.9%**	**39.5%**	**58.1%**	**46.5%**	**83.7%**	**0.0%**	**0.0%**
NOx Removed (Tons/Yr)	**0**	**926**	**1,312**	**1,929**	**1,543**	**2,778**	**0**	**0**
First Year Average Control Cost ($/Ton NOx Rem.)	**0**	**575**	**1,246**	**1,131**	**1,113**	**2,183**	**0**	**0**
Incremental Control Cost ($/Ton NOx Removed)	**Base**	**575**	**2,855**	**1,203**	**360**	**4,572**	**0**	**0**
		2-1	3-2	4-5	5-3	6-4		
SO2 Removal Rate (%)	**78.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
SO2 Removed (Tons/Yr)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
First Year Average Control Cost ($/Ton SO2 Rem.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Incremental Control Cost ($/Ton SO2 Removed)	**Base**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PM Removal Rate (%)	**99.05%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**66.67%**	**66.67%**
PM Removed (Tons/Yr)	**0**	**0**	**0**	**0**	**0**	**0**	**231**	**231**
First Year Average Control Cost ($/Ton PM Rem.)	**0**	**0**	**0**	**0**	**0**	**0**	**9,471**	**12,393**
Incremental Control Cost ($/Ton PM Removed)	**Base**	**0**	**0**	**0**	**0**	**0**	**9,471**	**12,393**
							7-1	8-1
PRESENT WORTH COST ($)	**0**	**5,737,428**	**18,406,629**	**24,609,016**	**18,950,887**	**66,159,816**	**24,211,412**	**31,186,332**

INPUT CALCULATIONS

Apache Unit 3 (ST3) Boiler Design: **Dry Bottom Turbo-fired**

Parameter	Current Operation	NOx Control					PM Control		Comments
		LNB w/OFA	ROFA	ROFA w/ Rotamix	LNB w/OFA & SNCR	LNB w/OFA & SCR	Polishing Fabric Filter	Fabric Filter	
Case	1	2	3	4	5	6	7	8	
NOx Emission Control System	OFA/UFA	LNB w/OFA	ROFA	ROFA w/ Rotamix	LNB w/OFA & SNCR	LNB w/OFA & SCR	OFA/UFA	OFA/UFA	
SO2 Emission Control System	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	Limestone Sctubber	
PM Emission Control System	ESP	ESP	ESP	ESP	ESP	ESP	Polishing Fabric Filter	Fabric Filter	
Unit Design and Coal Characteristics									
Type of Unit	PC	PC	PC	PC	PC	PC	PC	PC	
Net Power Output (kW)	195,000	195,000	195,000	195,000	195,000	195,000	195,000	195,000	
Net Plant Heat Rate (Btu/kW-Hr)	10,336	10,336	10,336	10,336	10,336	10,336	10,336	10,336	
Boiler Fuel	Colowyo	Colowyo	Colowyo	Colowyo	Colowyo	Colowyo	Colowyo	Colowyo	
Coal Heating Value (Btu/Lb)	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	
Coal Sulfur Content (wt.%)	0.36%	0.36%	0.36%	0.36%	0.36%	0.36%	0.36%	0.36%	
Coal Ash Content (wt.%)	6.19%	6.19%	6.19%	6.19%	6.19%	6.19%	6.19%	6.19%	
Boiler Heat Input, each (MMBtu/Hr)	2,016	2,016	2,016	2,016	2,016	2,016	2,016	2,016	
Coal Flow Rate (Lb/Hr)	193,800	193,800	193,800	193,800	193,800	193,800	193,800	193,800	
(Ton/Yr)	741,890	741,890	741,890	741,890	741,890	741,890	741,890	741,890	
(MMBtu/Yr)	15,431,305	15,431,305	15,431,305	15,431,305	15,431,305	15,431,305	15,431,305	15,431,305	
Emissions									
Uncontrolled SO2 (Lb/Hr)	1,394	304	304	304	304	304	304	304	
(Lb/MMBtu)	0.69	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
(Lb Moles/Hr)	21.76	4.75	4.75	4.75	4.75	4.75	4.75	4.75	
(Tons/Yr)	5,336	1,165	1,165	1,165	1,165	1,165	1,165	1,165	
SO2 Removal Rate (%)	78.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
(Lb/Hr)	1,090	0	0	0	0	0	0	0	
(Ton/Yr)	4,171	0	0	0	0	0	0	0	
SO2 Emission Rate (Lb/Hr)	304	304	304	304	304	304	304	304	
(Lb/MMBtu)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
(Ton/Yr)	1,165	1,165	1,165	1,165	1,165	1,165	1,165	1,165	
Uncontrolled NOx (Lb/Hr)	867	867	867	867	867	867	867	867	
(Lb/MMBtu)	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	
(Lb Moles/Hr)	28.88	28.88	28.88	28.88	28.88	28.88	28.88	28.88	
(Tons/Yr)	3,318	3,318	3,318	3,318	3,318	3,318	3,318	3,318	
NOx Removal Rate (%)	0.0%	27.9%	39.5%	58.1%	46.5%	83.7%	0.0%	0.0%	
(Lb/Hr)	0	242	343	504	403	726	0	0	
(Lb Moles/Hr)	0.00	8.06	11.42	16.79	13.43	24.18	0.00	0.00	
(Ton/Yr)	0	926	1,312	1,929	1,543	2,778	0	0	
NOx Emission Rate (Lb/Hr)	867	625	524	363	464	141	867	867	
(Lb/MMBtu)	0.43	0.31	0.26	0.18	0.23	0.07	0.43	0.43	
(Ton/Yr)	3,318	2,392	2,006	1,389	1,775	540	3,318	3,318	
Uncontrolled Fly Ash (Lb/Hr)	9,597	91	91	91	91	91	91	91	
(Lb/MMBtu)	4.762	0.045	0.045	0.045	0.045	0.045	0.045	0.045	
(Lb Moles/Hr)	319.8	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
(Tons/Yr)	36,738	347	347	347	347	347	347	347	
Fly Ash Removal Rate (%)	99.05%	0.00%	0.00%	0.00%	0.00%	0.00%	66.67%	66.67%	
(Lb/Hr)	9,506	0	0	0	0	0	60	60	
(Ton/Yr)	36,391	0	0	0	0	0	231	231	
Fly Ash Emission Rate (Lb/Hr)	91	91	91	91	91	91	30	30	
(Lb/MMBtu)	0.045	0.045	0.045	0.045	0.045	0.045	0.015	0.015	
(Ton/Yr)	347	347	347	347	347	347	116	116	

Parameter	Current Operation	NOx Control					PM Control		Comments
		LNB w/OFA	ROFA	ROFA w/ Rotamix	LNB w/OFA & SNCR	LNB w/OFA & SCR	Polishing Fabric Filter	Fabric Filter	
Case	1	2	3	4	5	6	7	8	
General Plant Data									
Annual Operation (Hours/Year)	7,656	7,656	7,656	7,656	7,656	7,656	7,656	7,656	
Annual On-Site Power Plant Capacity Factor	87.4%	0.87	0.87	0.87	0.87	0.87	0.87	0.87	
Economic Factors									
Interest Rate (%)	7.10%	7.10%	7.10%	7.10%	7.10%	7.10%	7.10%	7.10%	
Discount Rate (%)	7.10%	7.10%	7.10%	7.10%	7.10%	7.10%	7.10%	7.10%	
Plant Economic Life (Years)	20	20	20	20	20	20	20	20	
Installed Capital Costs									
NOx Emission Control System ($2007)	0	4,760,000	9,616,084	12,623,773	12,541,130	48,740,300	0	0	
SO2 Emission Control System ($2007)	0	0	0	0	0	0	0	0	
PM Emission Control System ($2007)	0	0	0	0	0	0	15,866,667	23,800,000	
Total Emission Control Systems ($2007)	0	4,760,000	9,616,084	12,623,773	12,541,130	48,740,300	15,866,667	23,800,000	
NOx Emission Control System ($/kW)	0	24	49	65	64	250	0	0	
SO2 Emission Control System ($/kW)	0	0	0	0	0	0	0	0	
PM Emission Control System ($/kW)	0	0	0	0	0	0	81	122	
Total Emission Control Systems ($/kW)	0	24	49	65	64	250	81	122	
Total Fixed Operating & Maintenance Costs									
Operating Labor ($)	0	0	0	0	0	0	0	0	
Maintenance Material ($)	0	32,000	48,000	48,000	51,000	132,000	45,016	45,016	
Maintenance Labor ($)	0	48,000	72,000	72,000	76,500	198,000	67,524	67,524	
Administrative Labor ($)	0	0	0	0	0	0	0	0	
Total Fixed O&M Cost ($)	0	80,000	120,000	120,000	127,500	330,000	112,540	112,540	
Annual Fixed O&M Cost Escalation Rate (%)	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	
Water Cost									
Makeup Water Usage (Gpm)	0	0	0	0	0	0	0	0	
Unit Price ($/1000 Gallons)	1.22	1.22	1.22	0.00	1.22	1.22	1.22	1.22	
First Year Water Cost ($)	0	0	0	0	0	0	0	0	
Annual Water Cost Escalation Rate (%)	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	
Reagent Cost	None	None	None	Anhydrous NH3	Urea	Anhydrous NH3	None	None	
Unit Cost ($/Ton)	0.00	0.00	0.00	400	370	400	0.00	0.00	
($/Lb)	0.000	0.000	0.000	0.200	0.185	0.200	0.000	0.000	
Molar Stoichiometry	0.00	0.00	0.00	0.50	0.45	1.00	0.00	0.00	
Reagent Purity (Wt.%)	100%	100%	100%	100%	100%	100%	100%	100%	
Reagent Usage (Lb/Hr)	0	0	0	46	145	275	0	0	
First Year Reagent Cost ($)	0	0	0	70,072	205,716	420,431	0	0	
Annual Reagent Cost Escalation Rate (%)	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	
SCR Catalyst / FF Bag Replacement Cost						SCR Catalyst	Bags	Bags	
Annual SCR Catalyst (m3) / No. FF Bags	0	0	0	0	0	98	700	1,050	
SCR Catalyst ($/m3) / Bag Cost ($/ea.)	3,000	3,000	3,000	3,000	3,000	3,000	104	104	
First Year SCR Catalyst / Bag Replace. Cost ($)	0	0	0	0	0	292,500	72,800	109,200	
Annual SCR Catalyst / Bag Cost Esc. Rate (%)	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	
FGD Waste Disposal Cost									
FGD Solid Waste Disposal Rate, Dry (Lb/Hr)	0	0	0	0	0	0	0	0	
FGD Waste Disposal Unit Cost ($/Dry Ton)	24.33	24.33	24.33	24.33	24.33	24.33	24.33	24.33	
First Year FGD Waste Disposal Cost ($)	0	0	0	0	0	0	0	0	
Annual Waste Disposal Cost Esc. Rate (%)	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	
Auxiliary Power Cost									
Auxiliary Power Requirement (% of Plant Output)	0.00%	0.00%	0.80%	1.06%	0.26%	0.51%	0.67%	0.51%	
(MW)	0.00	0.00	1.57	2.07	0.50	1.00	1.30	1.00	
Unit Cost ($2007/MW-Hr)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	
First Year Auxiliary Power Cost ($)	0	0	599,484	790,890	191,406	382,812	497,656	382,812	
Annual Power Cost Escalation Rate (%)	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	

CAPITAL COST

Apache Unit 3 (ST3)

Parameter	NOx Control										PM Control			
	LNB w/OFA		ROFA		ROFA w/ Rotamix		LNB w/OFA & SNCR		LNB w/OFA & SCR		Polishing Fabric Filter		Fabric Filter	
Case	2		3		4		5		6		7		8	
NOx Emission Control System	LNB w/OFA		ROFA		ROFA w/ Rotamix		LNB w/OFA & SNCR		LNB w/OFA & SCR		OFA/UFA		OFA/UFA	
SO2 Emission Control System	Limestone Sctubber		Limestone Sctubber		Limestone Sctubber		Limestone Sctubber		Limestone Sctubber		Limestone Sctubber		Limestone Sctubber	
PM Emission Control System	ESP		ESP		ESP		ESP		ESP		Polishing Fabric Filter		Fabric Filter	
CAPITAL COST COMPONENT	Factor/Source	Cost	Factor/Source	Cost	Factor/Source	Cost	Factor/Source	Cost	Factor/Source	Cost	Factor/Source	Cost	Factor/Source	Cost
LNB w/OFA or ROFA		LNB w/OFA		ROFA		ROFA		LNB w/OFA		LNB w/OFA				
Major Materials Design and Supply	Vendor	$2,000,000	Vendor	$3,627,000	Vendor	$3,627,000	Vendor	$2,000,000	Vendor	$2,000,000	Vendor	$0	Vendor	$0
Construction	50.0%	$1,000,000	Vendor	$1,346,524	Vendor	$1,346,524	50.0%	$1,000,000	50.0%	$1,000,000	50.0%	$0	50.0%	$0
Balance of Plant	30.0%	$600,000	30.0%	$1,088,100	30.0%	$1,088,100	30.0%	$600,000	30.0%	$600,000	20.0%	$0	20.0%	$0
Electrical (Allowance)	5.0%	$100,000	30.0%	$1,088,100	30.0%	$1,088,100	5.0%	$100,000	5.0%	$100,000	5.0%	$0	5.0%	$0
Owner's Costs	10.0%	$200,000	10.0%	$362,700	10.0%	$362,700	10.0%	$200,000	10.0%	$200,000	10.0%	$0	10.0%	$0
Surcharge	16.0%	$320,000	16.0%	$580,320	16.0%	$580,320	16.0%	$320,000	16.0%	$320,000	16.0%	$0	16.0%	$0
AFUDC	12.0%	$240,000	12.0%	$435,240	12.0%	$435,240	12.0%	$240,000	12.0%	$240,000	12.0%	$0	12.0%	$0
Subtotal		$4,460,000		$8,527,984		$8,527,984		$4,460,000		$4,460,000		$0		$0
Contingency	15.0%	$300,000	30.0%	$1,088,100	30.0%	$1,088,100	15.0%	$300,000	15.0%	$300,000	15.0%	$0	15.0%	$0
Total Capital Cost for LNB w/OFA or ROFA		$4,760,000		$9,616,084		$9,616,084		$4,760,000		$4,760,000		$0		$0
SNCR or SCR or Rotamix						Rotamix		SNCR		SCR				
Major Materials Design and Supply [1]	Vendor	$0	Vendor	$0	Vendor	$1,813,500	Vendor	$4,830,000	Vendor	$27,300,000	Vendor	$0	Vendor	$0
Contingency	20.0%	$0	20.0%	$0	Vendor	$448,841	20.0%	$966,000	20.0%	$5,460,000	20.0%	$0	20.0%	$0
Labor Premium	5.0%	$0	5.0%	$0	5.0%	$90,675	5.0%	$241,500	5.0%	$1,365,000	5.0%	$0	5.0%	$0
EPC Premium	8.0%	$0	8.0%	$0	8.0%	$145,080	8.0%	$386,400	8.0%	$2,184,000	8.0%	$0	8.0%	$0
Boiler Reinforcement (Allowance)	3.0%	$0	3.0%	$0	3.0%	$54,405	3.0%	$144,900	3.0%	$819,000	3.0%	$0	3.0%	$0
Sales Tax	1.1%	$0	1.1%	$0	1.1%	$19,949	1.1%	$53,130	1.1%	$300,300	1.1%	$0	1.1%	$0
Escalation	10.0%	$0	10.0%	$0	10.0%	$181,350	10.0%	$483,000	10.0%	$2,730,000	10.0%	$0	10.0%	$0
Contingency on Adders	3.0%	$0	3.0%	$0	3.0%	$54,405	3.0%	$144,900	3.0%	$819,000	3.0%	$0	3.0%	$0
Surcharge and AFUDC	11.0%	$0	11.0%	$0	11.0%	$199,485	11.0%	$531,300	11.0%	$3,003,000	11.0%	$0	11.0%	$0
Total Capital Cost for SNCR or SCR or Rotamix		$0		$0		$3,007,690		$7,781,130		$43,980,300		$0		$0
Dry or Wet FGD, FGC or Fabric Filter														
Major Materials Design and Supply	Vendor	$0	Vendor	$0	Vendor	$0	Vendor	$0	Vendor	$0	Vendor	$6,666,667	Vendor	$10,000,000
Construction	50.0%	$0	50.0%	$0	50.0%	$0	50.0%	$0	50.0%	$0	50.0%	$3,333,333	50.0%	$5,000,000
Balance of Plant	30.0%	$0	30.0%	$0	30.0%	$0	30.0%	$0	30.0%	$0	30.0%	$2,000,000	30.0%	$3,000,000
Electrical (Allowance)	5.0%	$0	5.0%	$0	5.0%	$0	5.0%	$0	5.0%	$0	5.0%	$333,333	5.0%	$500,000
Owner's Costs	10.0%	$0	10.0%	$0	10.0%	$0	10.0%	$0	10.0%	$0	10.0%	$666,667	10.0%	$1,000,000
Surcharge	16.0%	$0	16.0%	$0	16.0%	$0	16.0%	$0	16.0%	$0	16.0%	$1,066,667	16.0%	$1,600,000
AFUDC	12.0%	$0	12.0%	$0	12.0%	$0	12.0%	$0	12.0%	$0	12.0%	$800,000	12.0%	$1,200,000
Subtotal		$0		$0		$0		$0		$0		$0		$0
Surcharge and AFUDC	15.0%	$0	15.0%	$0	15.0%	$0	15.0%	$0	15.0%	$0	15.0%	$1,000,000	15.0%	$1,500,000
Total Capital Cost for Dry/Wet FGD, FGC or FF		$0		$0		$0		$0		$0		$15,866,667		$23,800,000

1 - Inculdes construction and balance of plant cost

Appendix B
BART Protocol

APPENDIX B

BART Protocol

Modeling Protocol for BART Control Technology Improvement Modeling Analyses for the AEPCO Apache Generating Station

Prepared for

Arizona Electric Power Cooperative, Inc.
A Touchstone Energy® Cooperative

Prepared by

CH2MHILL

July 2007

Contents

Tables

Figures

SECTION 1.0
Introduction

This document presents a modeling protocol for estimating the degree of visibility improvement from Best Available Retrofit Technology (BART) control technology options for the Arizona Electric Power Cooperative (AEPCO) Apache Generating Station Steam Units 1, 2 and 3. The Arizona Department of Environmental Quality (ADEQ) has identified that these three boiler units at the Apache Generating Station are BART eligible and must perform a Phase II BART analysis.

This protocol outlines the proposed approach for the modeling analysis for the Apache Generating Station. To a large extent, this protocol follows the methodology outlined in the Western Regional Air Partnership (WRAP) protocol for performing BART analyses (WRAP 2006). Any proposed deviations from that methodology are documented in this protocol. Section 2.0 describes the modeling system (CALPUFF) that will be used for the analyses. Sections 3.0 and 4.0 describe the proposed methodology for the CALMET meteorological model and the CALPUFF model, respectively. Section 5.0 presents a summary of the proposed approach for the CALPOST post-processor and Section 6.0 presents a brief description of the final report format for submittal to ADEQ. Section 7.0 contains a list of references cited in the protocol document.

SECTION 2.0

Model Selection

CH2M HILL will use the CALPUFF modeling system to assess the visibility impacts at Class I areas. Workgroups that represent the interests of the Federal Land Managers (FLM) recommend that an analysis of Class I area air quality and air quality related values (AQRVs) be performed for major sources located more than 50 km from these areas (USEPA 1998). The CALPUFF model is commonly recommended for these types of regulatory analyses.

The CALPUFF modeling system includes the CALMET meteorological model, a Gaussian puff dispersion model (CALPUFF) with algorithms for chemical transformation and deposition, and a post processor capable of calculating concentrations, visibility impacts, and deposition (CALPOST). The CALPUFF modeling system will be applied in a full, refined mode.

CH2M HILL will use the latest version (Version 6) of the CALPUFF modeling system preprocessors and models in lieu of the EPA-approved versions (Version 5). The Federal Land Managers (FLMs) and others have noted that the EPA-approved Version 5 contained errors and that a newer version should be used. In addition, Version 6 was used in the WRAP exemption modeling. Consequently, it was decided to use the latest (as of April, 2006) version of the CALPUFF modeling system (available at www.src.com):

- CALMET Version 6.211 Level 060414
- CALPUFF Version 6.112 Level 060412

SECTION 3.0

CALMET Methodology

3.1 Dimensions of the Modeling Domain

CH2M HILL will define domains for Mesoscale Model data (MM5), CALMET, and CALPUFF that will be slightly different than those established for the Arizona BART modeling in WRAP 2006. In addition, the CALMET and CALPUFF Lambert Conformal Conic (LCC) map projection will be based on a central meridian of 110 W rather than 97 W. This will put the central meridian near the center of the domain.

CH2M HILL will use the CALMET model to generate three-dimensional wind fields and other meteorological parameters suitable for use by the CALPUFF model. A CALMET modeling domain has been defined to allow for at least a 50-km buffer around all Class I areas within 300 km of the Apache Generating Station. Grid resolution for this domain will be 4-km. Figure 3-1 shows the extent of the proposed modeling domain.

The technical options recommended in WRAP 2006 will be used for CALMET. Vertical resolution of the wind field will include eleven layers, with vertical cell face heights as follows (in meters):

- 0, 20, 100, 200, 350, 500, 750, 1000, 2000, 3000, 4000, 5000

Also, following WRAP 2006, the maximum over-land mixing height (ZIMAX) will be set to 4500 meters based on the Colorado Department of Health and Environment (CDPHE) analyses of soundings for summer ozone events in the Denver area (CDPHE, 2005). The CDPHE analysis suggests mixing heights in the Denver area are often well above the CALMET default value of 3000 meters during the summer. For example, on some summer days, ozone levels are elevated all the way to 6000 meters MSL or beyond during some meteorological regimes, including some regimes associated with high ozone episodes. It is assumed that, like in Denver, mixing heights in excess of the 3,000 m AGL CALMET default maximum would occur in the domains considered for this analysis.

Table 3-1 lists the key user-specified options.

Figure 3-1
CALMET and CALPUFF Domains

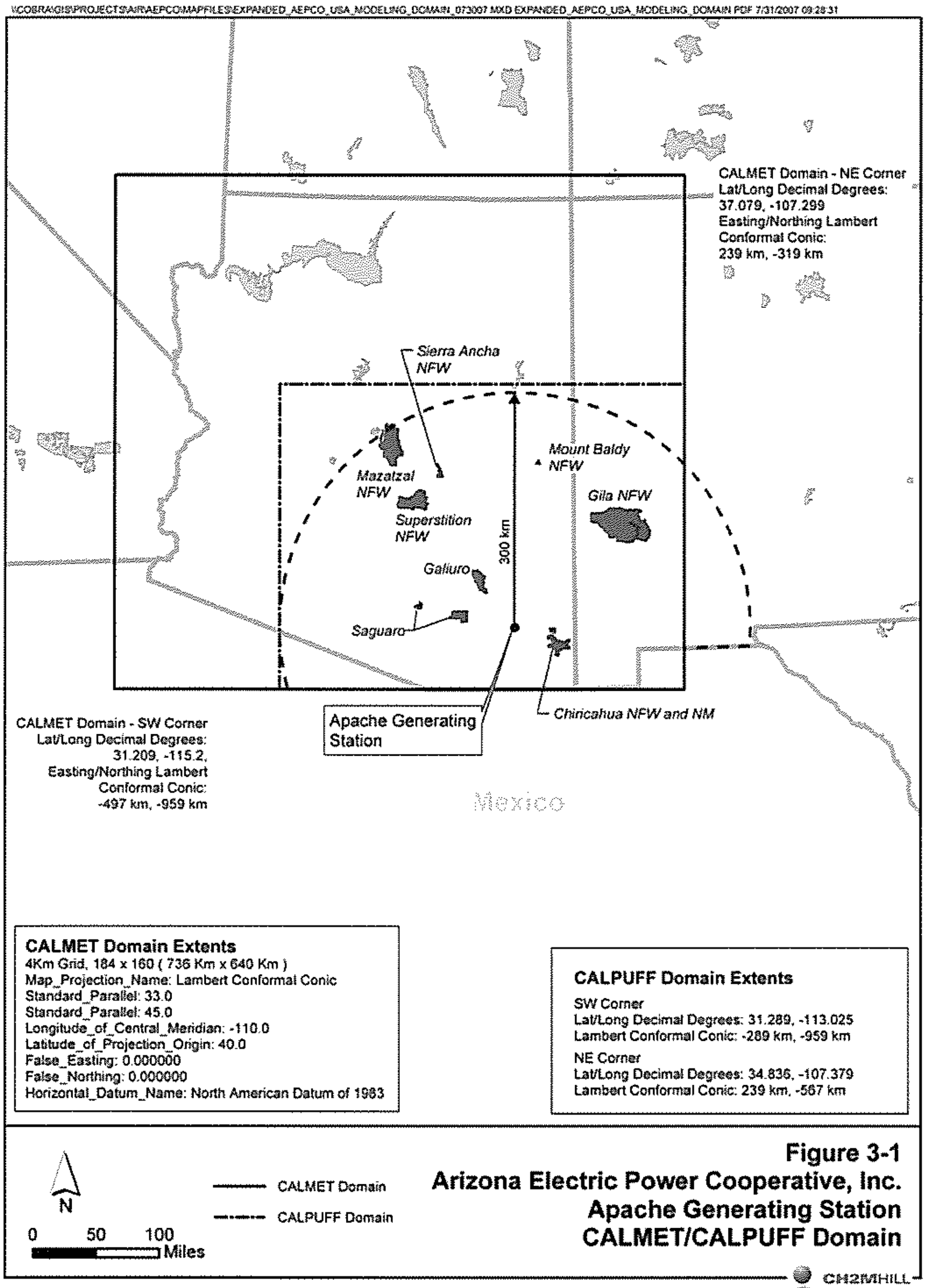

TABLE 3-1
User-Specified CALMET Options

Description	CALMET Input Parameter	Value
CALMET Input Group 2		
Map projection	PMAP	Lambert Conformal (LCC)
Grid spacing	DGRIDKM	4
Number vertical layers	NZ	11
Top of lowest layer (m)		20
Top of highest layer (m)		5000
CALMET Input Group 4		
Observation mode	NOOBS	1
CALMET Input Group 5		
Prognostic or MM-FDDA data switch	IPROG	14
Max surface over-land extrapolation radius (km)	RMAX1	50
Max aloft over-land extrapolations radius (km)	RMAX2	100
Radius of influence of terrain features (km)	TERRAD	10
Relative weight at surface of Step 1 field and obs	R1	100
Relative weight aloft of Step 1 field and obs	R2	200
CALMET Input Group 6		
Maximum over-land mixing height (m)	ZIMAX	4500

3.2 CALMET Input Data

CH2M HILL will run the CALMET model to produce three years of analysis: 2001, 2002, and 2003. CH2M HILL will use MM5 data as the basis for the CALMET wind fields. The horizontal resolution of the MM5 data is 36-km.

For 2001, CH2M HILL will use MM5 data at 36-km resolution that were obtained from the contractor (Alpine Geophysics) who developed the nationwide data for the EPA. For 2002, CH2M HILL will use 36-km MM5 data obtained from Alpine Geophysics, originally developed for WRAP. Data to be used for 2003 (also from Alpine Geophysics), at 36-km resolution, were developed by the Wisconsin Department of Natural Resources, the Illinois

Environmental Protection Agency, and the Lake Michigan Air Directors Consortium (Midwest RPO).

The MM5 data will be used as input to CALMET as the "initial guess" wind field. The initial guess field will be adjusted by CALMET for local terrain and land use effects to generate a Step 1 wind field, and then further refined using local surface observations to create a final Step 2 wind field.

Surface data for 2001-2003 will be obtained from the National Climatic Data Center (NCDC). In addition, concurrent surface data collected at the Apache Generating Station will be included. CH2M HILL will process data for all stations from the National Weather Service's (NWS) Automated Surface Observing System (ASOS) network that are in the domain. The surface data will be obtained in abbreviated DATSAV3 format. A conversion routine available from the TRC website will be used to convert the DATSAV3 files to CD-144 format for input to the SMERGE preprocessor and CALMET.

Land use and terrain data will be obtained from the U.S. Geological Survey (USGS). Land use data will be obtained in Composite Theme Grid (CTG) format from the USGS, and the Level I USGS land use categories will be mapped into the 14 primary CALMET land use categories. Surface properties such as albedo, Bowen ratio, roughness length, and leaf area index will be computed from the land use values. Terrain data will be taken from USGS 1-degree Digital Elevation Model (DEM) data, which are primarily derived from USGS 1:250,000 scale topographic maps. Missing land use data will be filled with a value that is appropriate for the missing area.

Precipitation data will be ordered from the National Climatic Data Center (NCDC). All available data in fixed-length, TD-3240 format will be ordered for the modeling domain. The list of available stations and stations that have collected complete data varies by year, but CH2M HILL will process all available stations/data within the domain for each year. Precipitation data will be prepared with the PXTRACT/PMERGE processors in preparation for use within CALMET.

Following the methodology recommended in WRAP 2006, no observed upper-air meteorological observations will be used as they are redundant to the MM5 data, and may introduce spurious artifacts in the wind fields. In the development of the MM5 data, the twice daily upper-air meteorological observations are used as input with the MM5 model. The MM5 estimates are nudged to the upper-air observations as part of the Four Dimensional Data Assimilation (FDDA). This results in higher temporal (hourly vs. 12-hour) and spatial (36 km vs. ~300 km) resolution for the upper-air meteorology in the MM5 field. These MM5 data are more dynamically balanced than those contained in the upper-air observations. Therefore the use of the upper-air observations with CALMET is not needed, and, in fact, will upset the dynamic balance of the meteorological fields potentially producing spurious vertical velocities.

3.3 Validation of CALMET Wind Field

CH2M HILL will use the CalDESK data display and analysis system (v2.97, Enviromodeling Ltd.) to view plots of wind vectors and other meteorological parameters to evaluate the CALMET wind fields. We will use observed weather conditions, as depicted in surface and upper-air weather maps from the National Oceanic and Atmospheric Administration (NOAA) Central Library U.S. Daily Weather Maps Project (http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html), to compare to the CalDESK displays.

SECTION 4.0

CALPUFF Methodology

4.1 CALPUFF Modeling

CH2M HILL will drive the CALPUFF model with the meteorological output from CALMET over the CALPUFF modeling domain (Figure 3-1). The CALPUFF model will be used to predict visibility impacts for the pre-control (baseline) scenario for comparison to the predicted impacts for post-control scenarios.

4.1.1 Background Ozone and Ammonia

Hourly values of background ozone concentrations will be used by CALPUFF for the calculation of SO_2 and NO_X transformation with the MESOPUFF II chemical transformation scheme. CH2M HILL will use the hourly ozone data generated for the WRAP BART analysis for 2001, 2002, and 2003.

For periods of missing hourly ozone data, the chemical transformation will rely on a monthly default value of 80 ppb. Background ammonia will be set to 1 ppb as recommended in WRAP 2006.

4.1.2 Stack Parameters

The baseline stack parameters will be the same as those used in the WRAP-RMC exemption modeling. Post-control stack parameters will reflect any anticipated changes from operation of the control technology alternatives that are being evaluated.

4.1.3 Pre-Control Emission Rates

Pre-control emission rates will reflect normal maximum capacity 24-hour emissions that may occur under the source's current permit. The emission rates will reflect actual emissions under normal operating conditions. As described by the EPA in the *Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations; Final Rule* (40 CFR Part 51; July 6, 2005, pg 39129):

> *The emissions estimates used in the models are intended to reflect steady-state operating conditions during periods of high-capacity utilization. We do not generally recommend that emissions reflecting periods of start-up, shutdown, and malfunction be used...*

CH2M HILL will use available CEM data to determine the baseline 24-hour emission rates. Data will reflect operations from 2002 through 2006.

Although the WRAP Exemption Modeling evaluated emissions of NOx, SO2, and PM2.5, particulate matter speciation data from the USEPA or National Park Service are proposed for this analysis (USEPA 2007, NPS 2007). Therefore emissions will be modeled for the following species:

- Sulfur dioxide (SO_2)
- Nitrogen oxides (NO_x)
- Coarse particulate ($PM_{2.5} <$ diameter $\leq PM_{10}$)
- Fine particulate (diameter $\leq PM_{2.5}$)
- Elemental carbon (EC)
- Organic aerosols (SOA)
- Sulfates (SO4)

4.1.4 Post Control Emission Rates

Post-control emission rates will reflect the effects of the emissions control scenario under consideration. Modeled pollutants will be the same as listed for the pre-control scenario.

4.1.5 Modeling Process

The CALPUFF modeling for the control technology options will follow this sequence:

- Model pre-control (baseline) emissions
- Determine the degree of visibility improvement
- Model other control scenarios if applicable
- Determine the degree of visibility improvement
- Factor visibility results into BART "5-step" evaluation

4.2 Receptor Grids and Coordinate Conversion

The TRC COORDS program will be used to convert the latitude/ longitude coordinates to LCC coordinates for the meteorological stations and source locations. The USGS conversion program PROJ (version 4.4.6) will be used to convert the National Park Service (NPS) receptor location data from latitude/longitude to LCC.

For the Class I areas that are within 300 km of the Apache Generating Station, discrete receptors for the CALPUFF modeling will be taken from the NPS database for Class I area modeling receptors. The entire area of each Class I area that is within or intersects the 300 km circle (Figure 3-1) will be included in the modeling analysis. The following lists the Class I areas that will be modeled for the Apache Generating Station:

- Chiricahua Wilderness and National Monument
- Galiuro Wilderness
- Saguaro National Park
- Gila Wilderness
- Superstition Wilderness
- Mount Baldy Wilderness
- Sierra Ancha Wilderness
- Mazatzal Wilderness

SECTION 5.0

Visibility Post-processing

5.1 CALPOST

The CALPOST processor will be used to determine 24-hour average visibility results. Output will be specified in deciview (dv) units.

Calculations of light extinction will be made for each pollutant modeled. The sum of all extinction values will be used to calculate the delta-dv change relative to natural background. Default extinction coefficients for each species, as shown below, will be used.

- Ammonium sulfate 3.0
- Ammonium nitrate 3.0
- PM coarse (PM_{10}) 0.6
- PM fine ($PM_{2.5}$) 1.0
- Organic carbon 4.0
- Elemental carbon 10.0

CALPOST visibility Method 6 (MVISBK=6) will be used for the determination of visibility impacts. Monthly average relative humidity factors [f(RH)] will be used in the light extinction calculations to account for the hygroscopic characteristic of sulfate and nitrate particles. Monthly f(RH) values will be the same as the Class I area specific values used in the WRAP-RMC BART modeling.

The natural background conditions as a reference for determination of the delta-dv change will represent the average natural concentration for western Class I areas. Table 5-1 lists the annual average species concentrations from the EPA Guidance.

TABLE 5-1
Average Natural Levels of Aerosol Components

Aerosol Component	Average Natural Concentration ($\mu g/m^3$) for Western Class I Areas
Ammonium Sulfate	0.12
Ammonium Nitrate	0.10
Organic Carbon	0.47
Elemental Carbon	0.02
Soil	0.50
Coarse Mass	3.0

Note: Taken from Table 2-1 of Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule.

SECTION 6.0

Presentation of Results

The results for a given year of meteorology, each emission control scenario, and each Class I area will be presented as the maximum Δdv and 98th percentile Δdv over the 3-year period, as well as the maximum number of days per year that the maximum Δdv exceeds 0.5 dv.

For the BART analysis, the model results for each emission control scenario will be compared to those for the baseline scenario. Incremental differences between increasing levels of control will also be evaluated.

The methodology and results of the CALPUFF modeling analyses will be presented in a technical report for each unit that is subject to BART. Input and output files for the CALMET/CALPUFF modeling and post-processing will be provided in electronic format to the ADEQ. Larger files such as binary files generated by CALMET will not be included on the submitted disks, but any omitted files will be provided electronically upon request.

SECTION 7.0

References

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MEMORANDUM CH2MHILL

Arizona BART Modeling Protocol and CALMET Settings by WRAP

TO: Arizona Electric Power Cooperative, Inc.

FROM: John Frohning/ CH2M HILL
Gordon Frisbie/ CH2M HILL
Mary Beth Yansura/ CH2M HILL

DATE: August 28, 2007

Introduction

CH2M HILL has evaluated the current Western Regional Air Partnership (WRAP) Best Available Retrofit Technology (BART) applicability assessments for facilities in Arizona. In their BART modeling, WRAP used the CALPUFF modeling system to estimate eligible facilities' impacts on federal CLASS I areas within 300-km of each facility.

Prior to conducting the modeling analysis, WRAP prepared a modeling protocol[1] which outlines their approach and selection of control parameter values (settings) used in the CALMET and CALPUFF control files. The WRAP protocol gives a fairly good support for their selection of several settings. However, some of the selected settings are not supported with any documentation including some of the CALMET settings used in the generation of the three-dimensional wind field.

Influence of Surface Meteorological Data

MM5 gridded three-dimensional meteorological data are used as the initial guess wind field in CALMET for both the WRAP and the proposed CH2M HILL analyses. These data can be further adjusted by introducing observational meteorological data and specifying the radius of influence of this data within or near the CALMET domain. The extent of this influence is established by the following parameters.

- IEXTRP – Extrapolation of surface wind observations to upper layers
- R1 - Relative weighting of the first guess field and observations in the surface layer
- RMAX1 - Maximum radius of influence over land in the surface layer
- R2 - Relative weighting of the first guess field and observations in the layers aloft
- RMAX2 - Maximum radius of influence over land aloft

R1 and R2 values describe the distance from the observed meteorological data station at which the surface data and initial guess wind field (MM5 data as adjusted for terrain and other effects) are weighted equally (i.e., the point at which the surface station is weighted

[1] *CALMET/CALPUFF Protocol for BART Exemption Screening Analysis for Class I Areas in the Western United States.* August 2006

50% and the initial guess wind field is weighted 50%). After the R1 and R2 distances, the initial guess wind field has more weight in the calculation of the CALMET wind field.

Generally, the R1 and R2 values are set to less than the RMAX1 and RMAX2 values to allow better smoothing between the observational data and the initial guess wind field.

Comparison of WRAP Settings and Proposed Settings

The R1, R2, RMAX1, and RMAX2 values selected by WRAP are not explained in the modeling protocol. The WRAP selected values for IEXTRP, R1, R2, RMAX1, and RMAX2 are summarized below:

- IEXTRP = 1 (no extrapolation of surface observation data is done)
- R1 = 100 km
- R2 = 200 km
- RMAX1 = 50 km
- RMAX2 = 100 km

WRAP has R1 and R2 values that are larger than the RMAX1 and RMAX2 values. This means at the RMAX distances, the surface stations are weighted *greater* than the MM5 data. Defining the parameters in this way causes a noticeable boundary in the wind field at the RMAX distances. This effect is known as *crop circling* in the wind field because there is a well defined circle around the meteorological data station in the processed wind vector map, where there is a discrepancy between the surface station data and the MM5 data (see Figure 1 for selected day in the WRAP-defined wind field).

Crop circles in the wind field may result in inaccurate results from the CALPUFF modeling because the wind field may be either shifting the plume transport too greatly between individual time steps, or may push the plume back to the original cell in a small time step.

To alleviate this problem, it is proposed that the R1, R2, RMAX1, and RMAX2 values be modified to allow better smoothing in the wind field.

In addition, by using an IEXTRP value of 1, the WRAP CALMET processing prevents the surface stations from influencing the meteorological data above the surface layer (see Figure 2 for selected day at WRAP-defined IEXTRP value of 1). We are proposing to use an IEXTRP value of 4 (the CALMET default value) which allows some influence of the surface data on the layers above the surface.

After evaluating the locations of the meteorological stations and the proximity of the stations to each other and nearby terrain features, the proposed R1, R2, RMAX1, and RMAX2 values are summarized below.

- IEXTRP = 4 (similarity theory used)
- R1: 25-km
- R2: 25-km
- RMAX1: 50-km
- RMAX2: 50-km

Changing the IEXTRP, R1, R2, RMAX1, and RMAX2 to the values above results in better smoothing in the CALMET wind field at the RMAX distances and minimizes the crop circling affect surrounding each surface station. This also allows a reasonable amount of surface station influence on the upper layers of meteorological data. Figures 3 and 4 present the resulting proposed wind fields that can be compared to the WRAP wind fields (Figures 1 and 2).

Figure 1 – WRAP Wind Field, Surface Layer, Date: 12/08/2001, Hour: 02

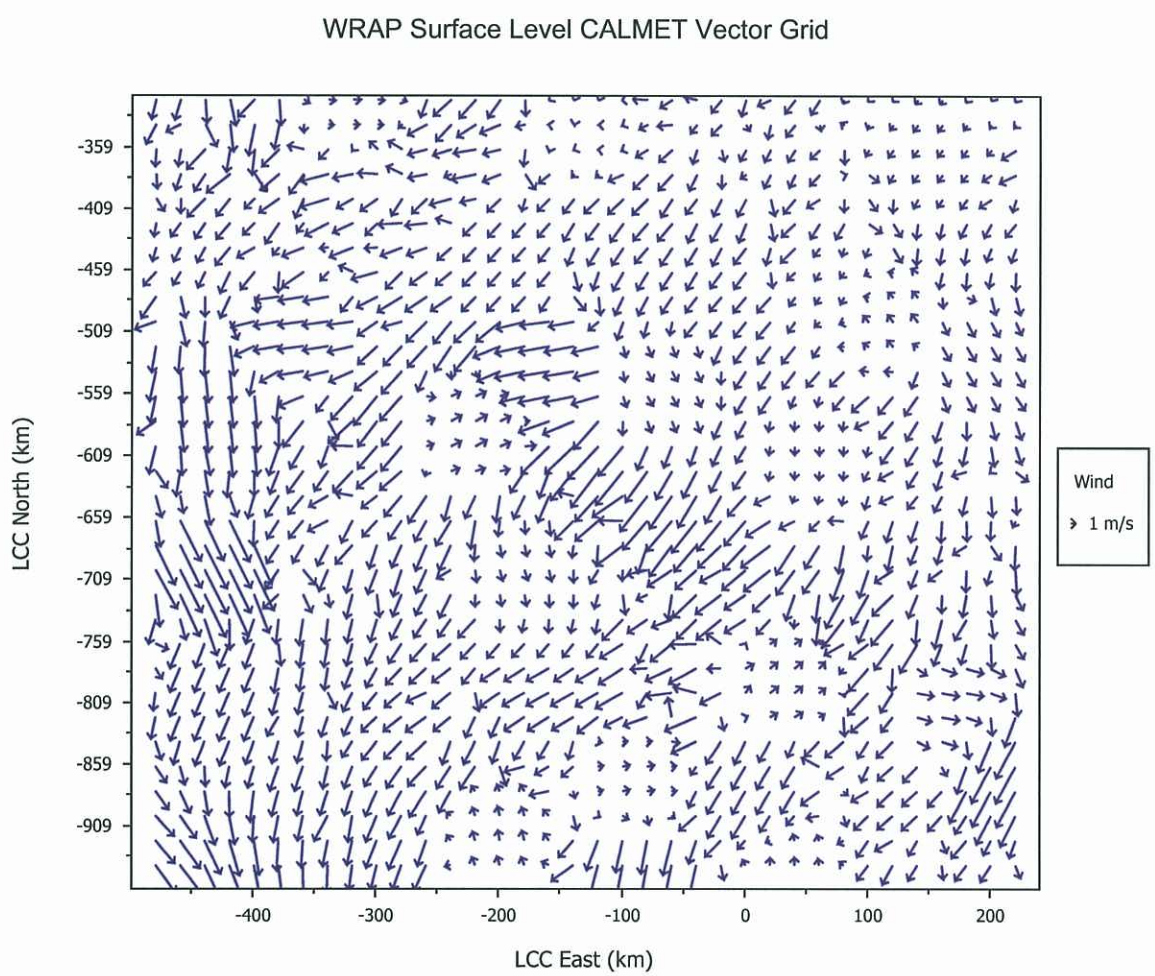


Figure 2 – WRAP Wind Field, Layer 2, Date: 12/08/2001, Hour: 02

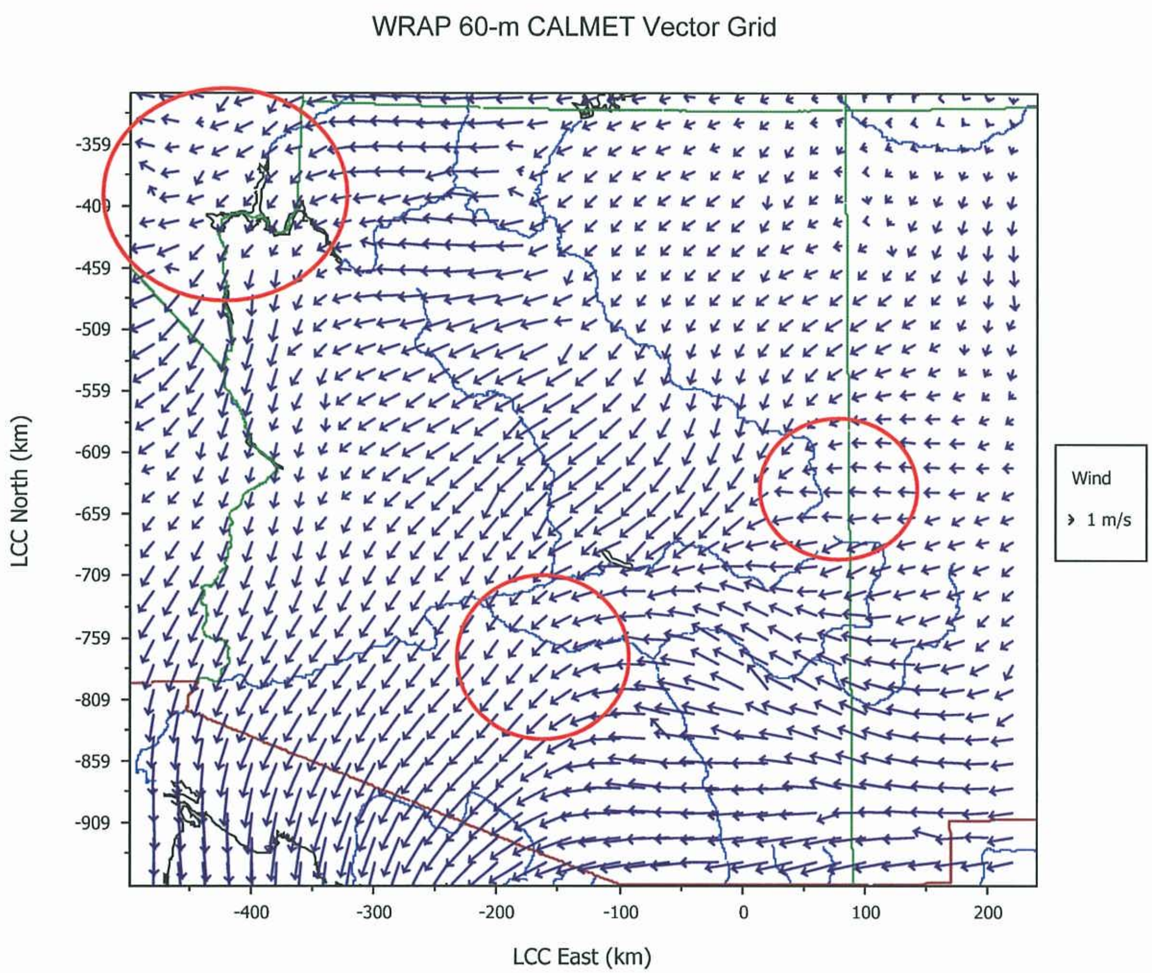


Figure 3 – Proposed Revised Wind Field, Surface Layer, Date: 12/08/2001, Hour: 02

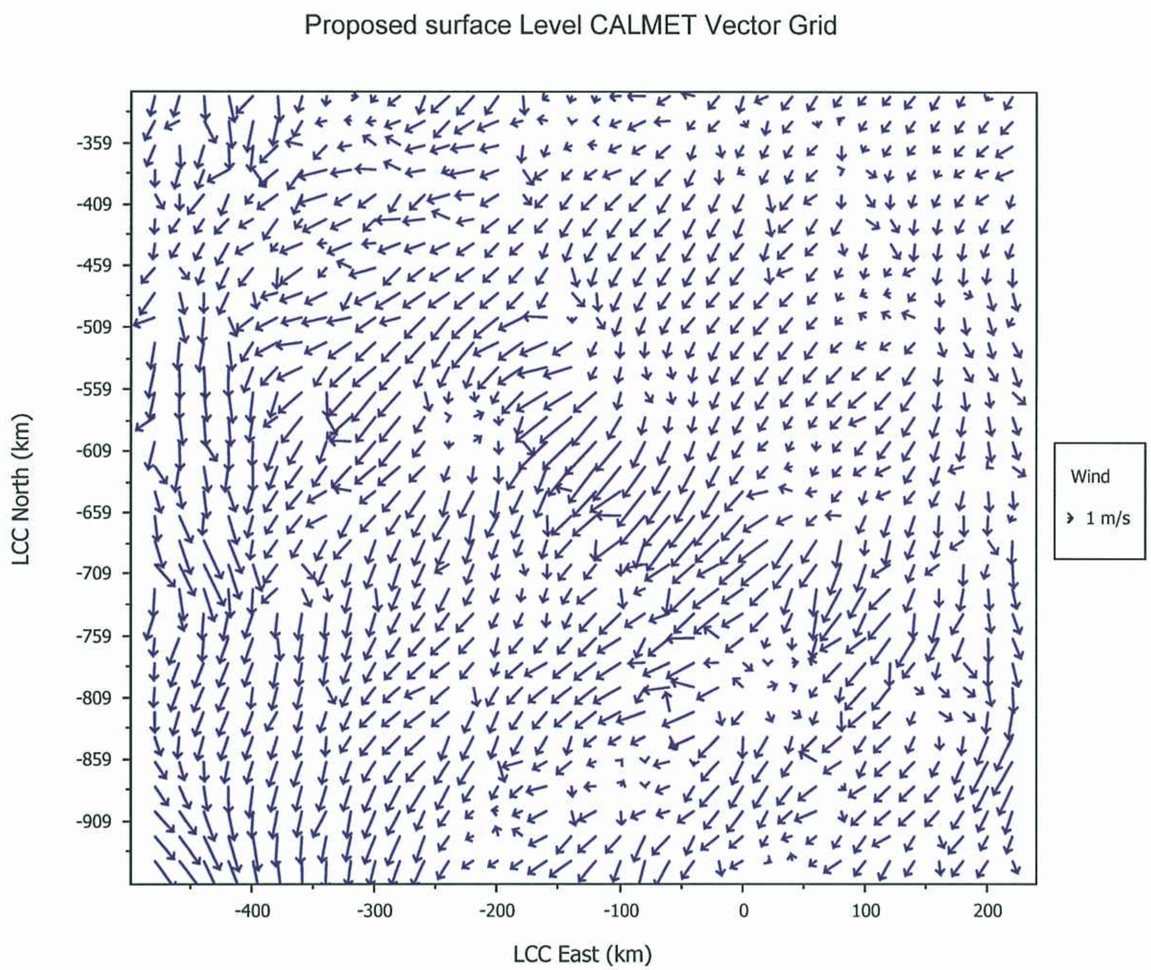
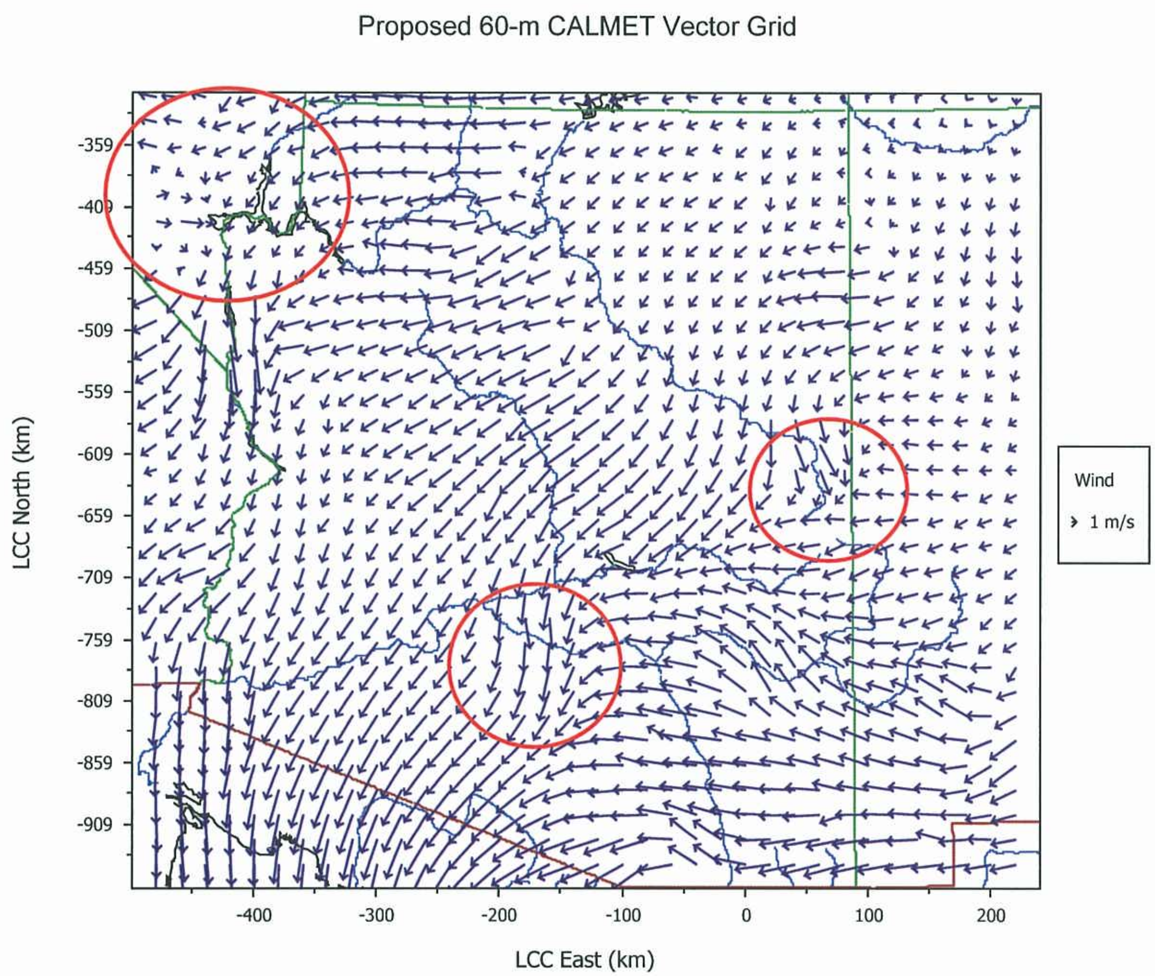


Figure 4 – Proposed Revised Wind Field, Layer 2, Date: 12/08/2001, Hour: 02



From: Eric C. Massey <Massey.Eric@azdeq.gov>
To: mfreeark@ssw.coop <mfreeark@ssw.coop>
Cc: Leonard H. Montenegro <Montenegro.Leonard@azdeq.gov>; Jie Yang <Yang.Jie@azdeq.gov>; Trevor Baggiore <Baggiore.Trevor@azdeq.gov>; jandrew@aepco.coop <jandrew@aepco.coop>; Montalvo, Kara/PHX
Sent: Fri Sep 28 10:54:01 2007
Subject: RE: AEPCO Modeling Protocol Amendment

Michelle,

Thank you for the follow-up call yesterday, as well as your e-mail. I've looked through my records, and I can't find any evidence that I responded to the September 7, 2007, e-mail. Please accept my sincere apologies. It seems that I had all of the information to respond, and I thought I had responded, but perhaps I am remembering my intention to respond. In either event, I apologize for the delay in responding. Here is ADEQ's response to AEPCO's request that we reconsider some of our previous decisions:

ADEQ has reevaluated AEPCO's proposal of using IEXTRP=4 in their CALPUFF modeling for BART analysis. This option allows CALMET to extrapolate surface observational wind to upper level. ADEQ agrees that this option will allow a fully use of the on-site meteorological data. ADEQ approves the use of IEXTRP=4 for AEPCO's BART modeling. Considering the CALMET model only extrapolating surface wind up to the user specified minimum mixing height (ZIMIN) (Version 6), ADEQ requires that ZIMIN be set as the same value that WRAP used in their BART screening modeling, i.e. 50 meters. This setting will eliminate surface extrapolation at layers that are more than 50 meters above the ground. This is appropriate since the upper layer wind should be free of surface terrain impact and is most likely to be different from the surface wind.

ADEQ also approves the use of default BIAS values, i.e. zero for all vertical layers. Since there will be no upper air observational data to be processed in CALMET, the actual value of BIAS should have no impact on model behavior.

Finally, to confirm our discussion yesterday, I had spoken with the Regional Modeling Center, and they indicated that they would not be able to re-run the original modeling analysis for us. My recommendation would be to work with your consultant to run two versions of your model. One with the correct coal data, before applying any potential BART controls, and the second with the correct coal data along with the BART controls. When submitting this analysis to us, please just remind us that the original modeling anlaysis used an incorrect set of emissions factors, and that you re-ran the model to provide us with more representative information about the source's pre-BART impacts.

Thanks for the reminders, and I am terribly sorry that this did not get communicated to you sooner.

Eric

To: "Eric C. Massey" <Massey.Eric@azdeq.gov>
From: James Andrew/Power Production/SSW
Date: 09/07/2007 09:59AM
cc: Kara.Montalvo@ch2m.com, "Eric C. Massey" <Massey.Eric@azdeq.gov>, mfreeark@ssw.coop, "Leonard H. Montenegro" <Montenegro.Leonard@azdeq.gov>, "Jie Yang" <Yang.Jie@azdeq.gov>
Subject: RE: AEPCO Modeling Protocol Amendment

Eric,

AEPCO respectfully submits this response to ADEQ's comments on the BART Modeling Protocol Amendment.

We realize that ADEQ has stated that it cannot support the default CALMET setting of IEXTRP = 4 but AEPCO urges ADEQ to reconsider. Applying the default CALMET setting of IEXTRP = 4, as proposed by CH2MHILL, will allow AEPCO to more fully utilize actual on-site hourly meteorological data for Apache Generating Station to achieve the goal of CALMET/CALPUFF modeling - to generate spatially and temporally refined estimates of pollutant dispersion.

In CALMET, MM5 data are used as the "first guess" wind fields. Geographically, the MM5 data only have a 36-kilometer resolution, and the smallest MM5 time interval is set by surface data which "nudges" the estimates at 3-hour intervals. CALPUFF modeling estimates dispersion at 1-hour intervals, and allows the pollutant dispersion to be estimated over a finer horizontal grid resolution.

Using MM5 to generate CALPUFF results could miss many wind events and wind shifts in the upper air that may exist at finer spatial and temporal resolution. This could be especially important for locations with on-site hourly meteorological data, or within areas with higher resolution terrain influence. Extrapolating the surface observations takes advantage of finer resolution data to determine the initial direction that the plume is traveling in the layers aloft. Note that this influence is regulated by using the Similarity Theory in Version 6 of CALMET, which uses Beljaars and Holtslag (1991) as opposed to van Ulden and Holtslag (1985) to correct some errors with interpolation above 200 meters.

WRAP has stated that there is a conflict between IEXTRP = 4 and RMIN2 = 4. RMIN2 is the distance surrounding an upper air station where surface data will not be used to extrapolate to upper layers. Since no upper air observation station data were used in developing the grid, this is a moot point. The false velocities WRAP is referencing would occur at the boundary of the 4-km radius around upper air stations that don't exist.

Additionally, setting BIAS to 0 does not create an unlimited influence of extrapolated surface wind in the upper layers. The BIAS value changes the weighting of the upper air station or surface station data based on vertical extrapolation. Changing this setting would be negligible in this case since there is no upper air data to weigh against in the wind field. The only change that would make a difference would be to completely eliminate the surface data influence for certain levels. However, since IEXTRP = 4, Similarity Theory is used so the surface station already has less influence on the higher vertical levels.

In summary, surface data provide actual meteorological conditions that are averaged at 1-hour intervals. These data capture real meteorological conditions that may not be accounted for in the coarse resolution of the MM5 data. Limiting the effects of these data to the 10 meter level, would neglect the actual dispersion of air pollutants above this level that would occur at these times. It would be more realistic to allow limited influence of the surface data in the levels above the 10 meter layer. These effects would be vertically limited by Similarity Theory, and horizontally by the R and RMAX values.

Thank you for your consideration.

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Appendix C
Additional BART Modeling Results

APPENDIX C

Additional BART Modeling Results

FIGURE C-1
NO_x Control Scenarios - Maximum Contributions to Visual Range Reduction at Gila Wilderness
Apache 3

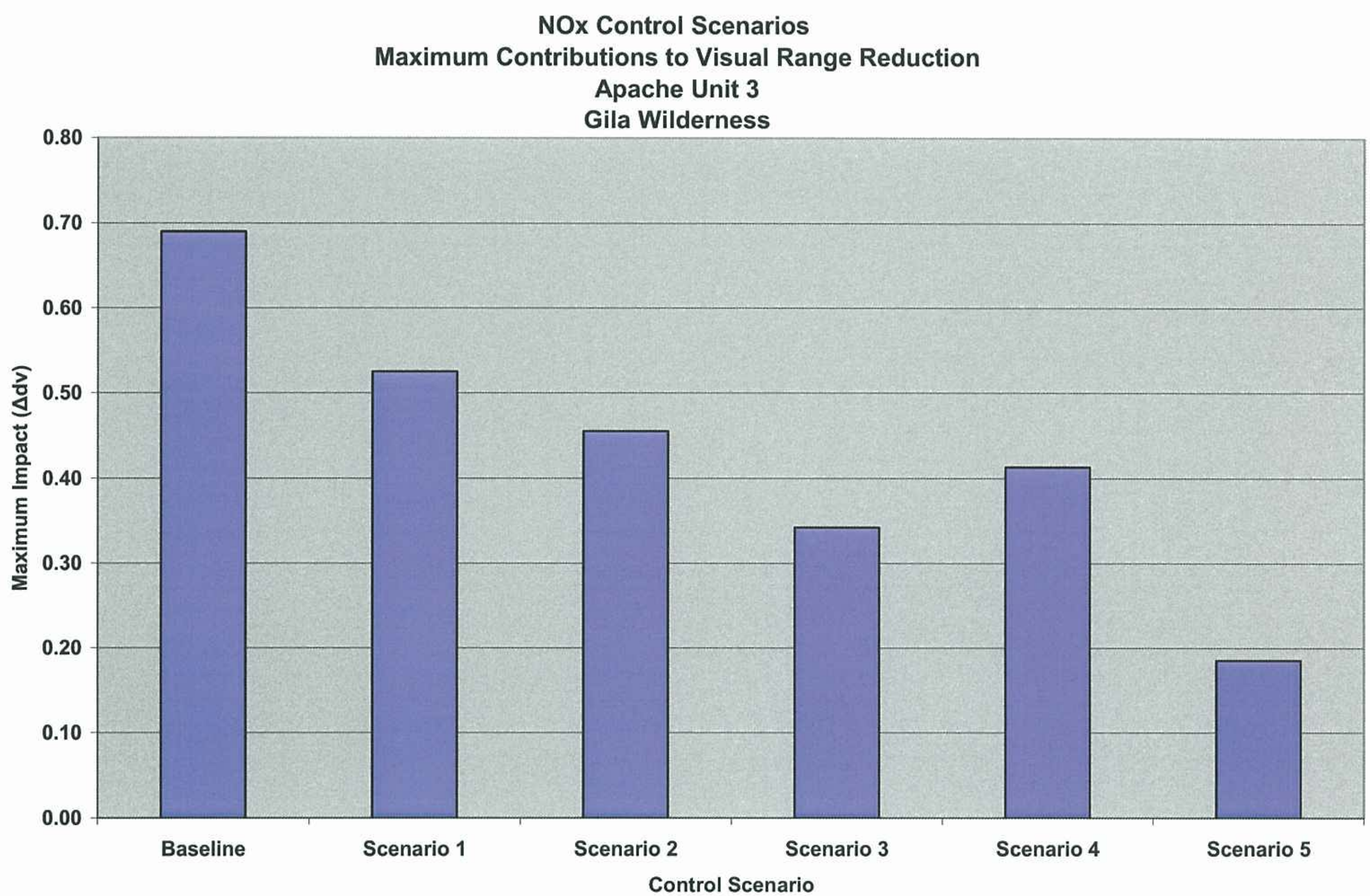

FIGURE C-2
NO_x Control Scenarios - Maximum Contributions to Visual Range Reduction at Mount Baldy Wilderness
Apache 3

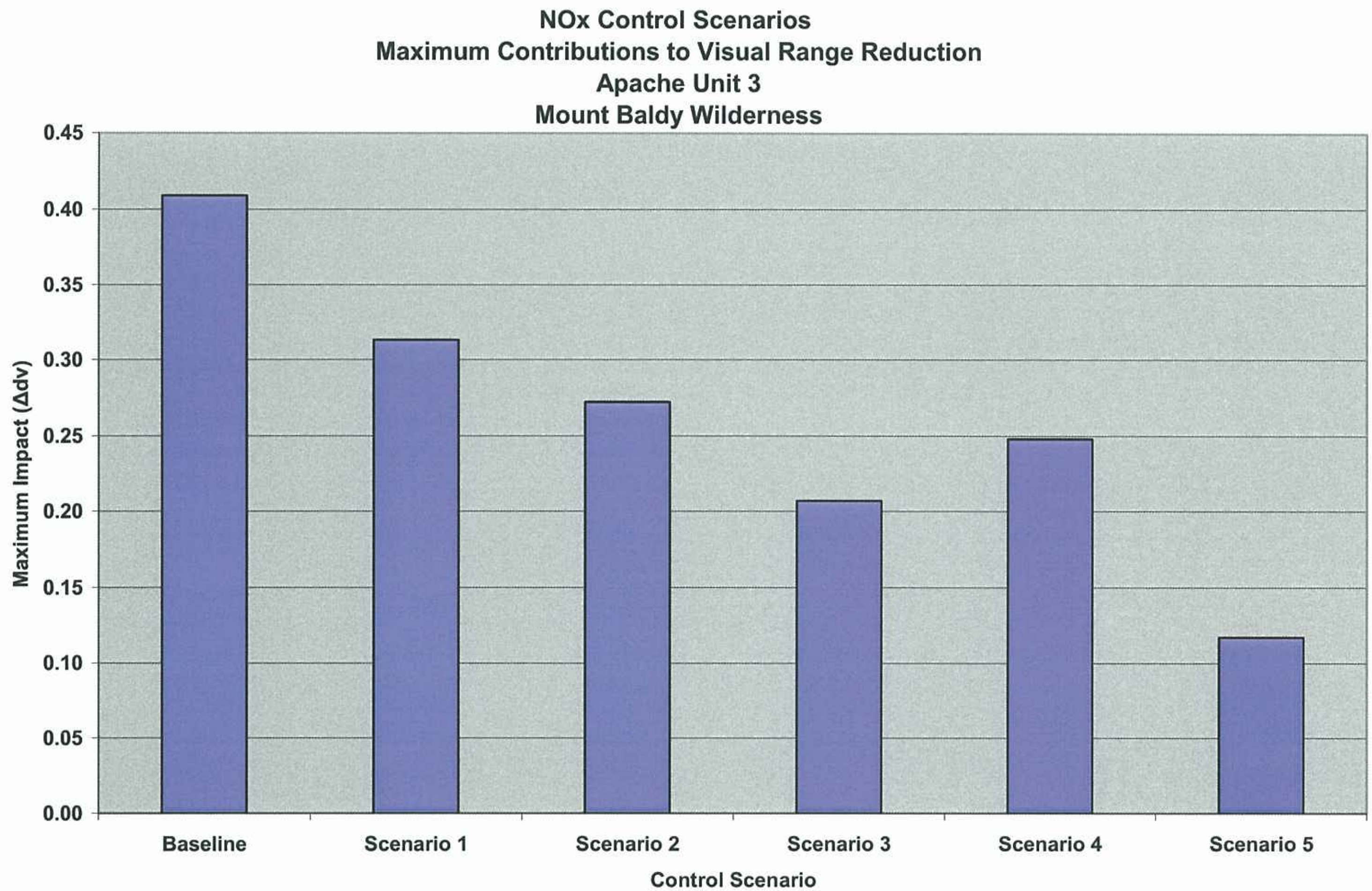

FIGURE C-3
NO_x Control Scenarios - Maximum Contributions to Visual Range Reduction at Sierra Ancha Wilderness
Apache 3

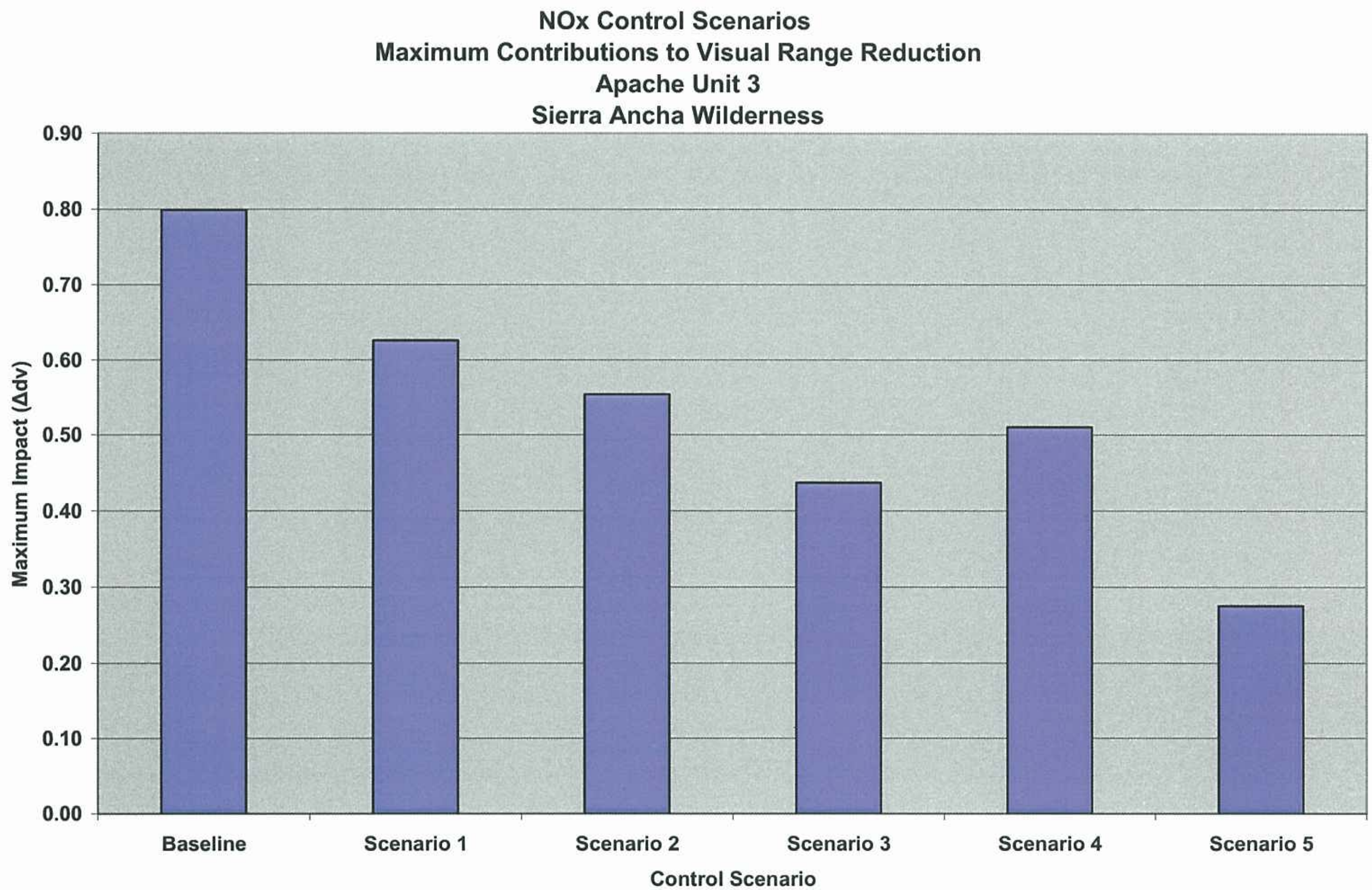

FIGURE C-4
NO_x Control Scenarios - Maximum Contributions to Visual Range Reduction at Mazatzal Wilderness
Apache 3

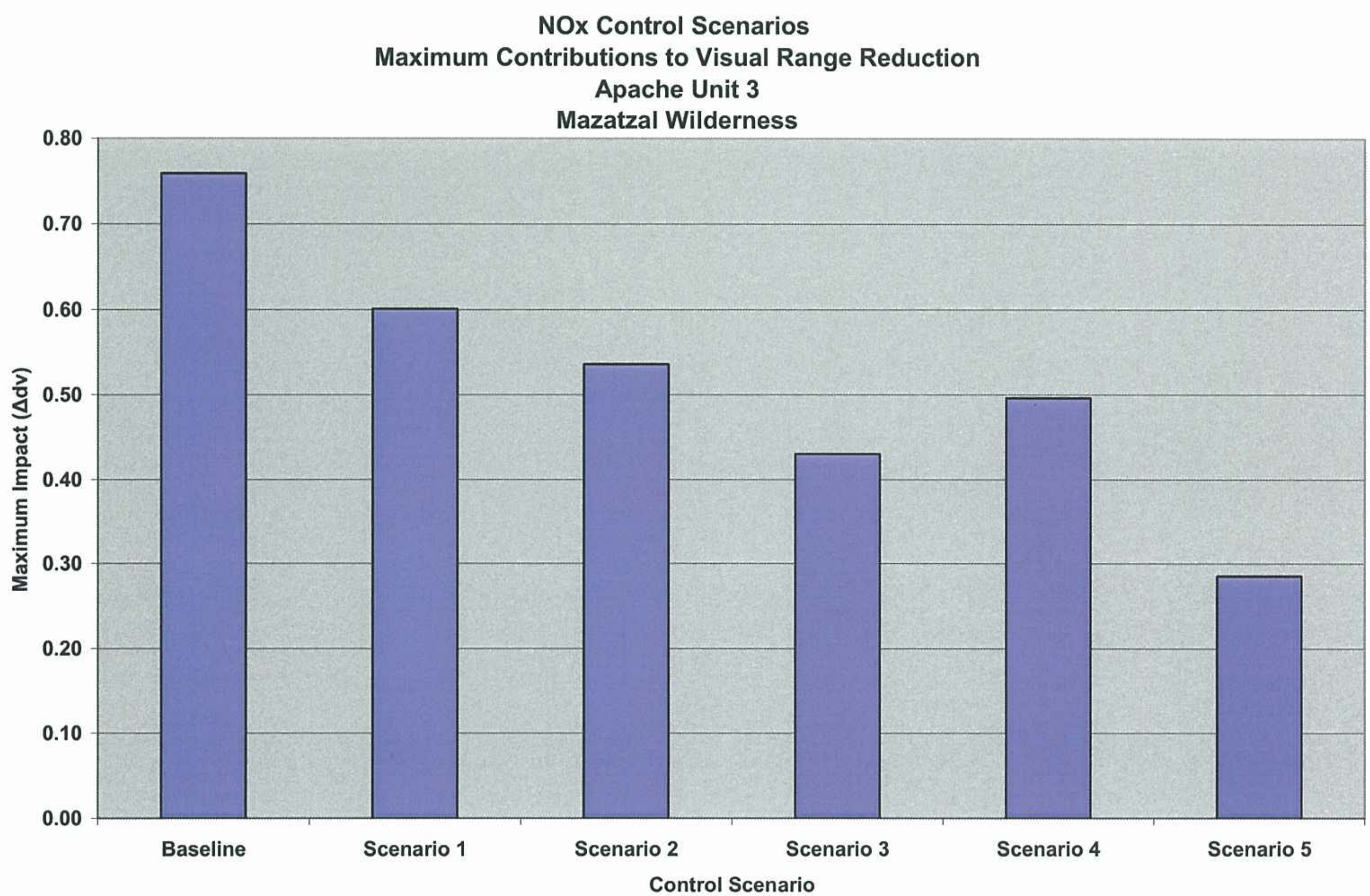

FIGURE C-5
NO_x Control Scenarios - Maximum Contributions to Visual Range Reduction at Pine Mountain Wilderness
Apache 3

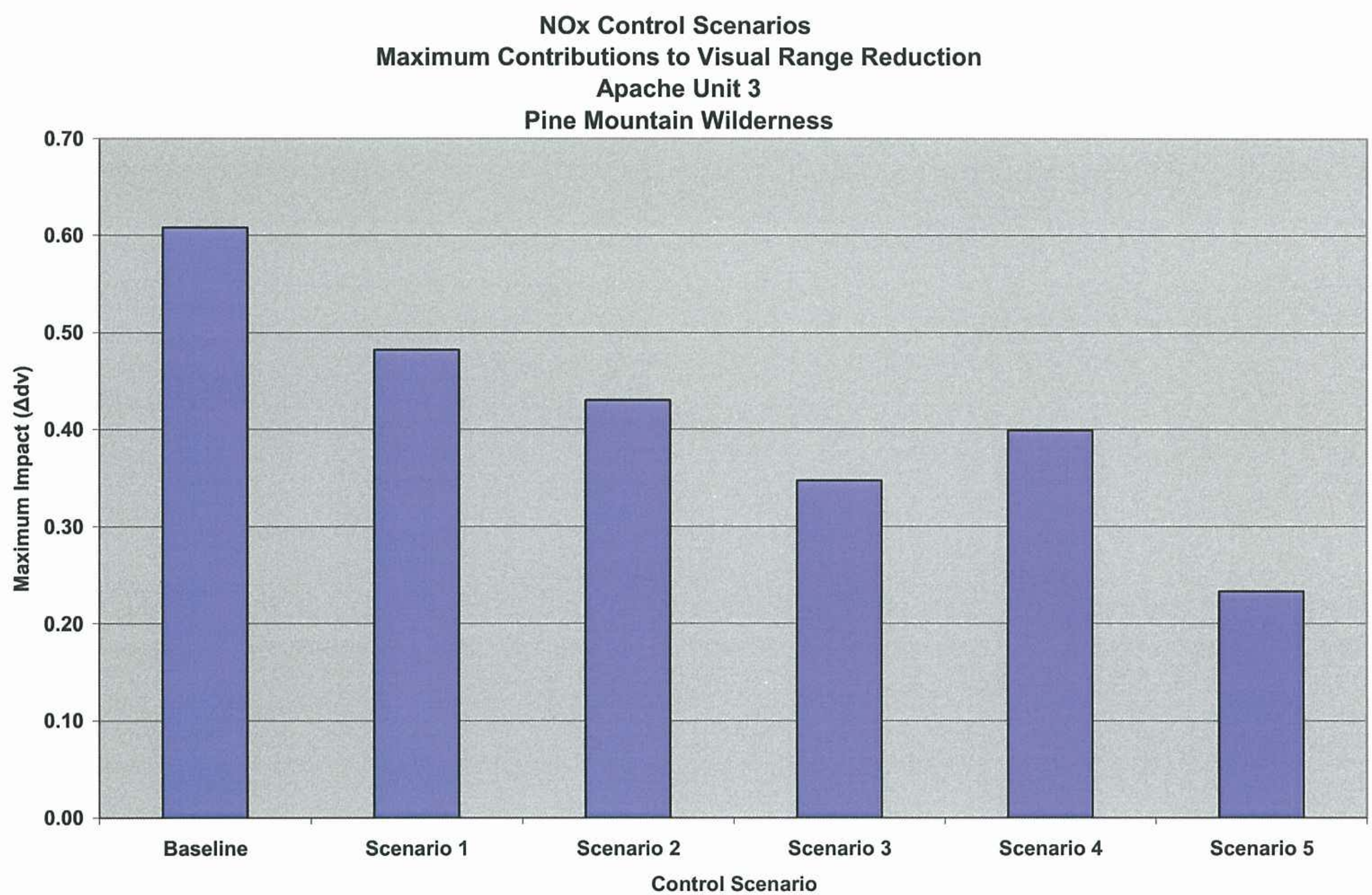

TABLE C-1
NO_x Control Scenario Results for Gila Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		2	0.000	0.000	0.000	0.000
1	LNB w/FGR	1	0.051	0.533	0.533	10.447
2	ROFA	0	0.069	1.634	0.817	23.685
3	ROFA w/Rotamix	0	0.108	2.182	1.091	20.202
4	LNB w/ FGD & SNCR	0	0.083	1.718	0.859	20.694
5	SCR	0	0.151	6.062	3.031	40.148

TABLE C-2
NO_x Control Scenario Results for Mount Baldy Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		0	0.000	0.000	0.000	0.000
1	LNB w/FGR	0	0.021	0.533	NA	25.372
2	ROFA	0	0.031	1.634	NA	52.717
3	ROFA w/Rotamix	0	0.044	2.182	NA	49.587
4	LNB w/ FGD & SNCR	0	0.037	1.718	NA	46.423
5	SCR	0	0.059	6.062	NA	102.751

TABLE C-3
NO_x Control Scenario Results for Sierra Ancha Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		2	0.000	0.000	0.000	0.000
1	LNB w/FGR	2	0.023	0.533	NA	23.166
2	ROFA	2	0.033	1.634	NA	49.522
3	ROFA w/Rotamix	0	0.051	2.182	1.091	42.781
4	LNB w/ FGD & SNCR	1	0.040	1.718	1.718	42.941
5	SCR	0	0.072	6.062	3.031	84.199

TABLE C-4
NO_x Control Scenario Results for Mazatzal Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		1	0.000	0.000	0.000	0.000
1	LNB w/FGR	1	0.027	0.533	NA	19.734
2	ROFA	1	0.038	1.634	NA	43.006
3	ROFA w/Rotamix	0	0.052	2.182	2.182	41.958
4	LNB w/ FGD & SNCR	0	0.042	1.718	1.718	40.896
5	SCR	0	0.071	6.062	6.062	85.385

TABLE C-5
NO_x Control Scenario Results for Pine Mountain Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		1	0.000	0.000	0.000	0.000
1	LNB w/FGR	0	0.015	0.533	0.533	35.521
2	ROFA	0	0.022	1.634	1.634	74.284
3	ROFA w/Rotamix	0	0.033	2.182	2.182	66.116
4	LNB w/ FGD & SNCR	0	0.025	1.718	1.718	68.705
5	SCR	0	0.051	6.062	6.062	118.869

TABLE C-6
Gila Wilderness NO_x Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	1	0.051	0.533	0.533	10.447
Scenario 5 vs. Scenario 1	1	0.100	5.529	5.529	55.295

TABLE C-7
Mount Baldy Wilderness NO_x Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	0	0.021	0.533	NA	25.372
Scenario 5 vs. Scenario 1	0	0.038	5.529	NA	145.513

TABLE C-8
Sierra Ancha Wilderness Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	0	0.023	0.533	NA	23.166
Scenario 5 vs. Scenario 1	2	0.049	5.529	2.765	112.847

TABLE C-9
Mazatzal Wilderness NO_x Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	0	0.027	0.533	NA	19.734
Scenario 5 vs. Scenario 1	1	0.044	5.529	5.529	125.670

TABLE C-10
Pine Mountain Wilderness NO_x Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 1 vs. Baseline	1	0.015	0.533	0.533	35.521
Scenario 5 vs. Scenario 1	0	0.036	5.529	NA	153.597

FIGURE C-6
NO_x Control Scenarios - Least Cost Envelope Gila Wilderness - Days Reduction
Apache 3

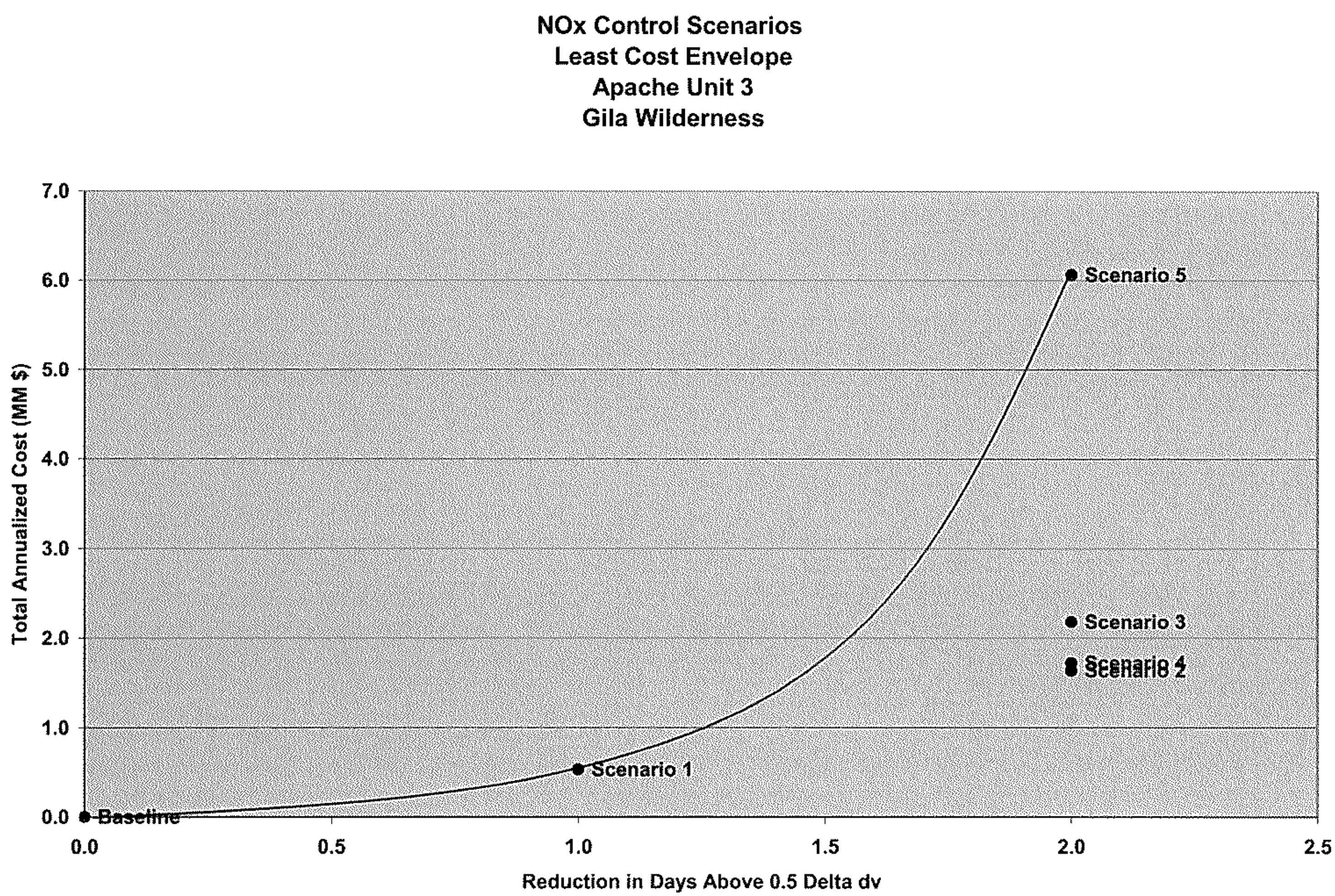

FIGURE C-7
NO_x Control Scenarios - Least Cost Envelope Gila Wilderness - 98th Percentile Reduction
Apache 3

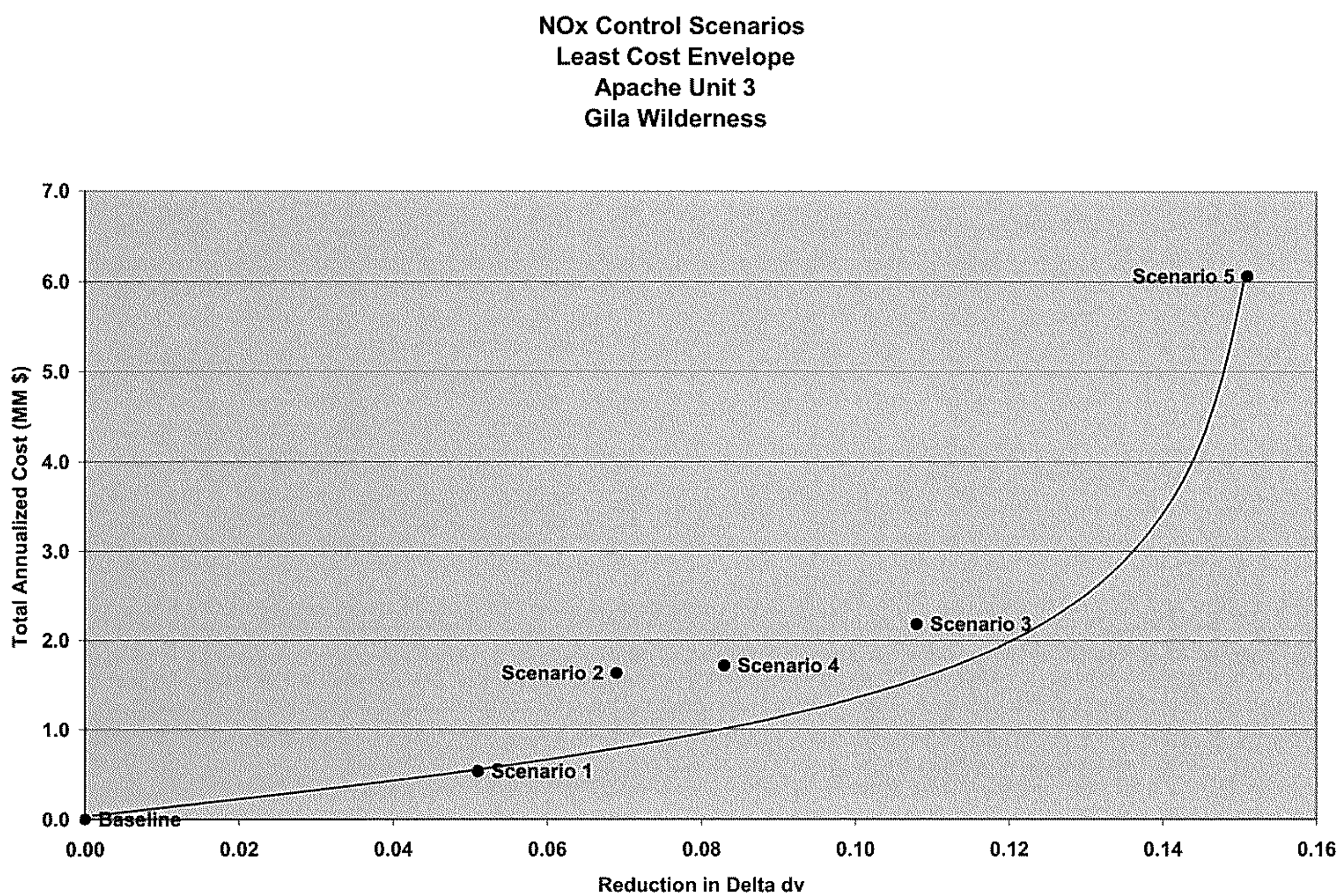

FIGURE C-8
NO_x Control Scenarios - Least Cost Envelope Mount Baldy Wilderness - Days Reduction
Apache 3

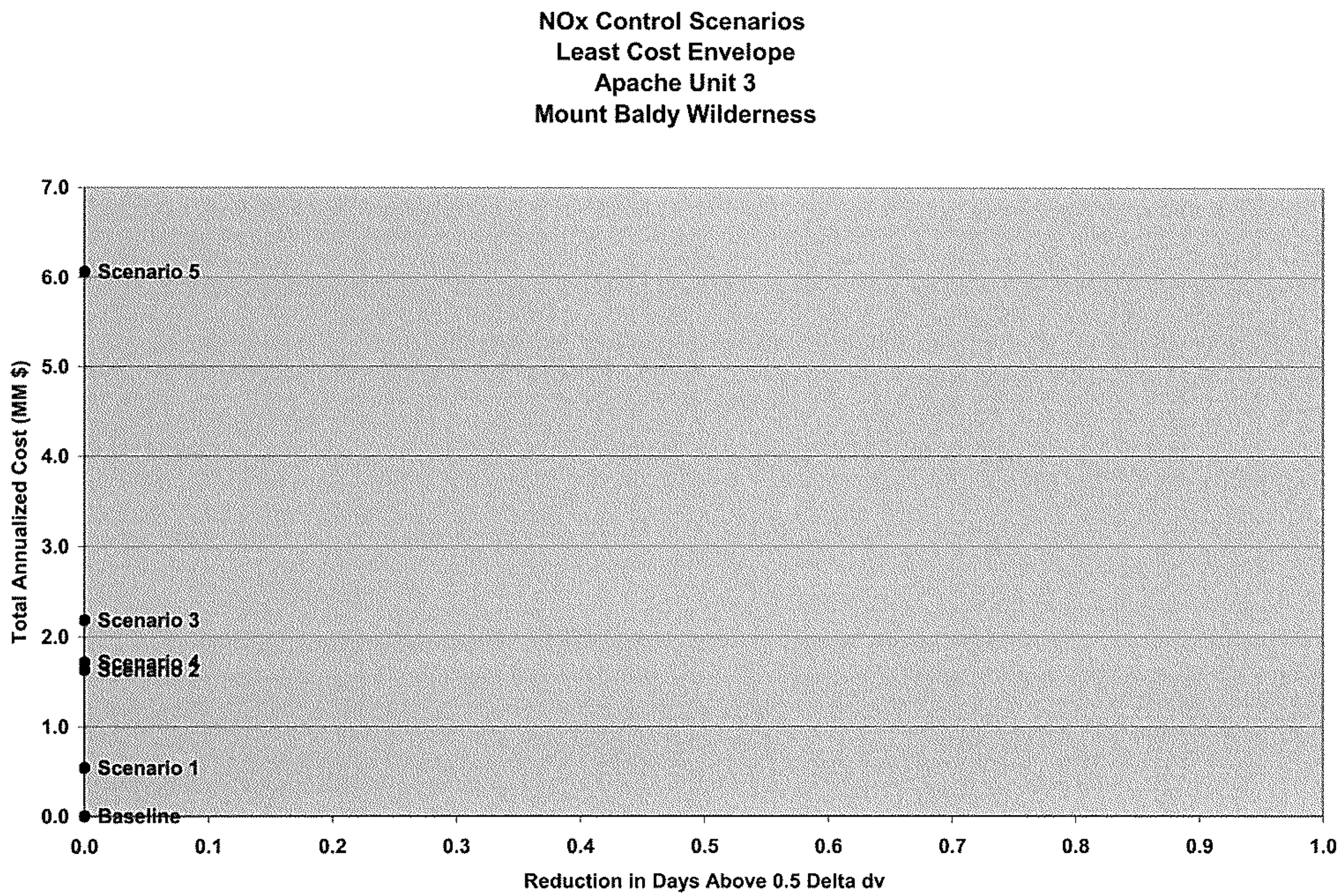

FIGURE C-9
NO_x Control Scenarios - Least Cost Envelope Mount Baldy Wilderness - 98th Percentile Reduction
Apache 3

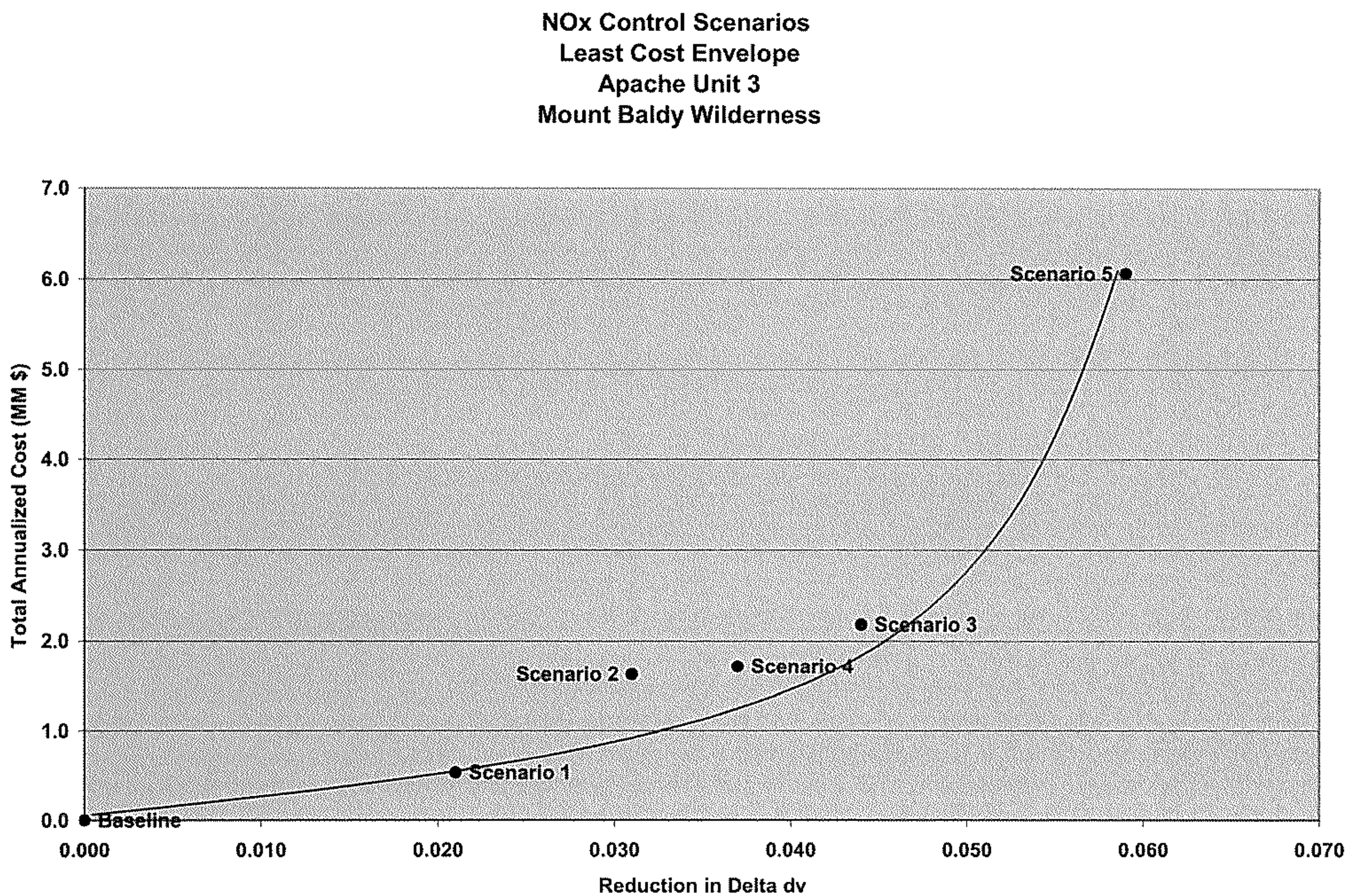

FIGURE C-10
NO_x Control Scenarios - Least Cost Envelope Sierra Ancha Wilderness - Days Reduction
Apache 3

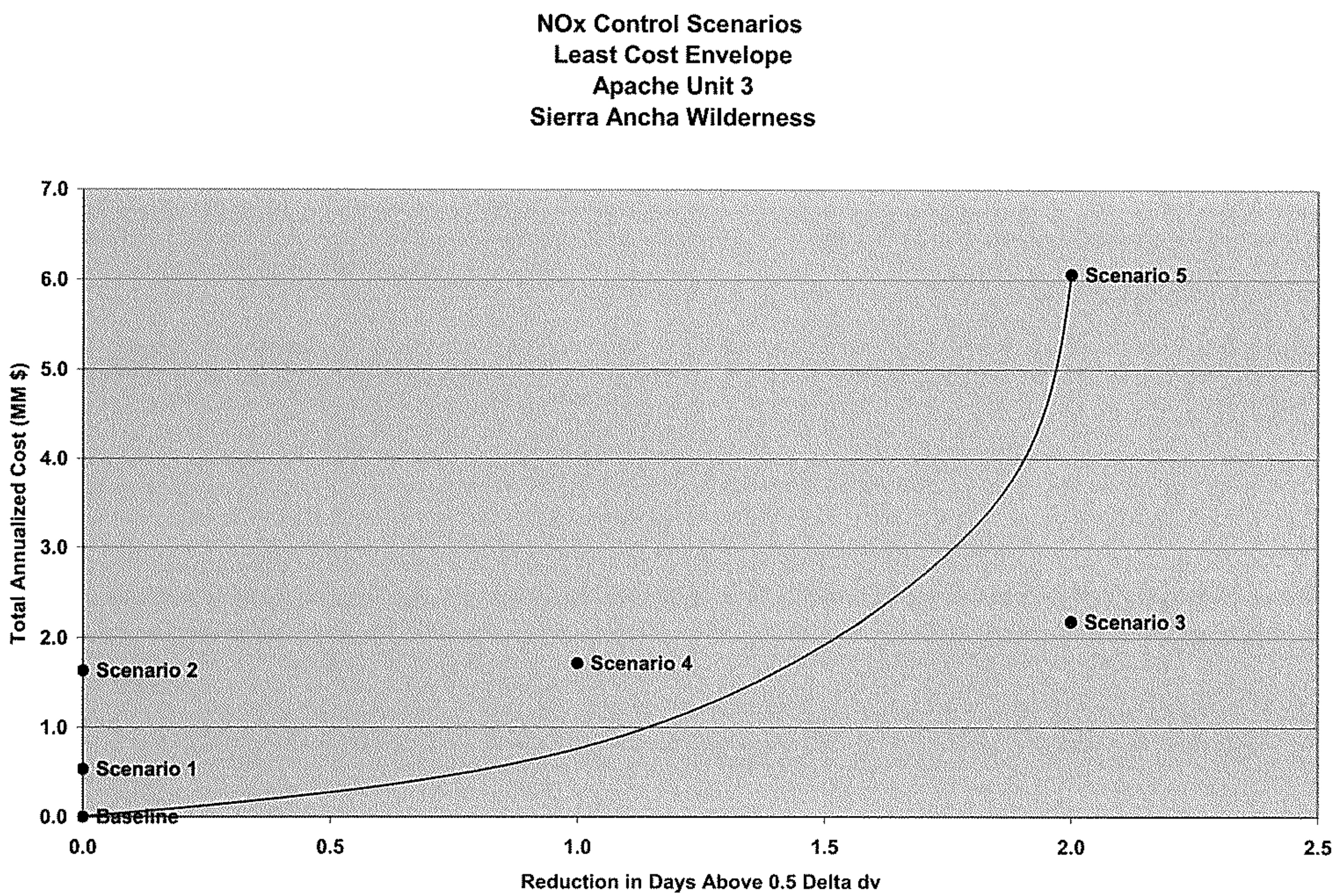

FIGURE C-11
NO_x Control Scenarios - Least Cost Envelope Sierra Ancha Wilderness - 98th Percentile Reduction
Apache 3

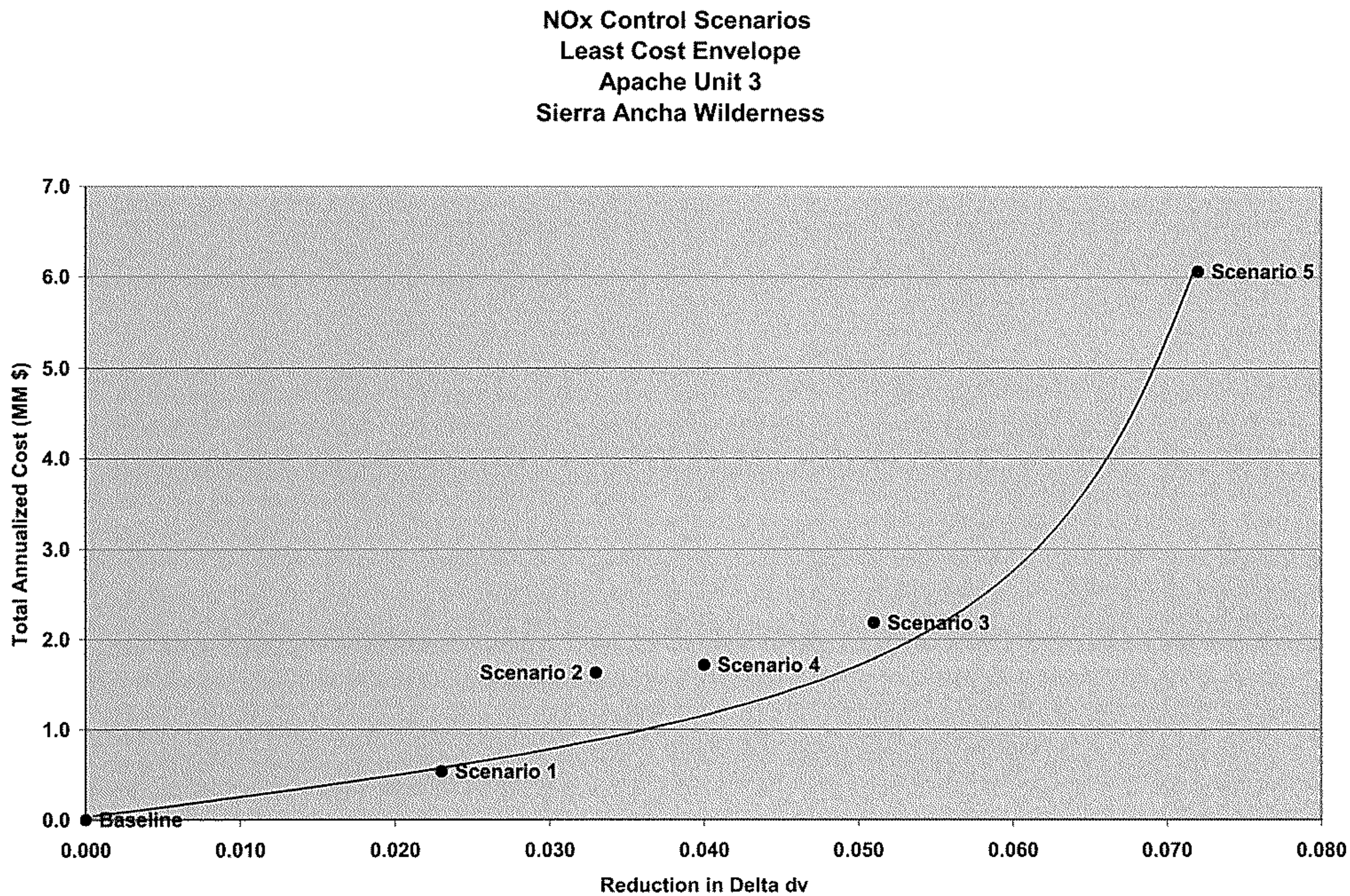

FIGURE C-12
NO_x Control Scenarios - Least Cost Envelope Mazatzal Wilderness - Days Reduction
Apache 3

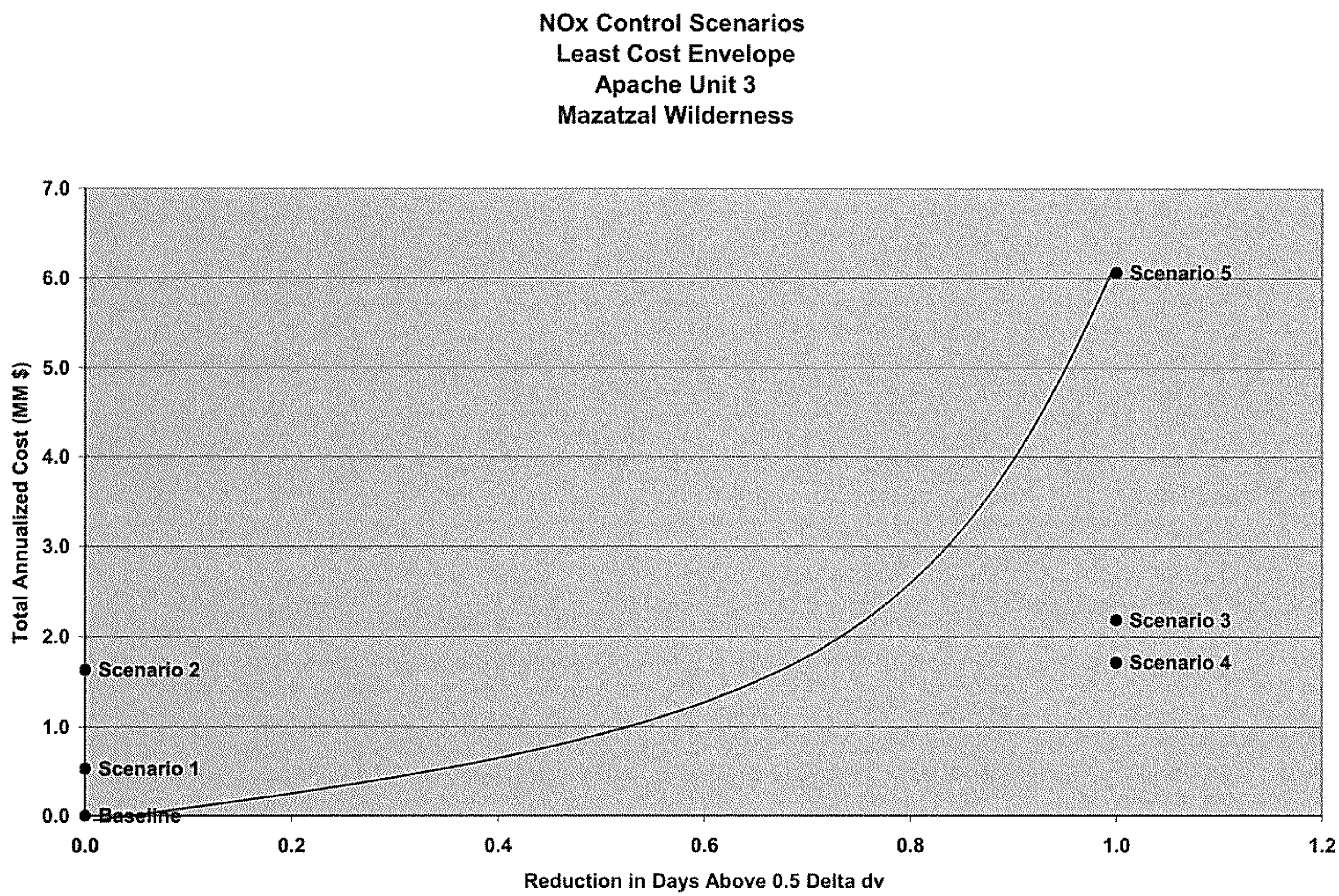

FIGURE C-13
NO_x Control Scenarios - Least Cost Envelope Mazatzal Wilderness - 98th Percentile Reduction
Apache 3

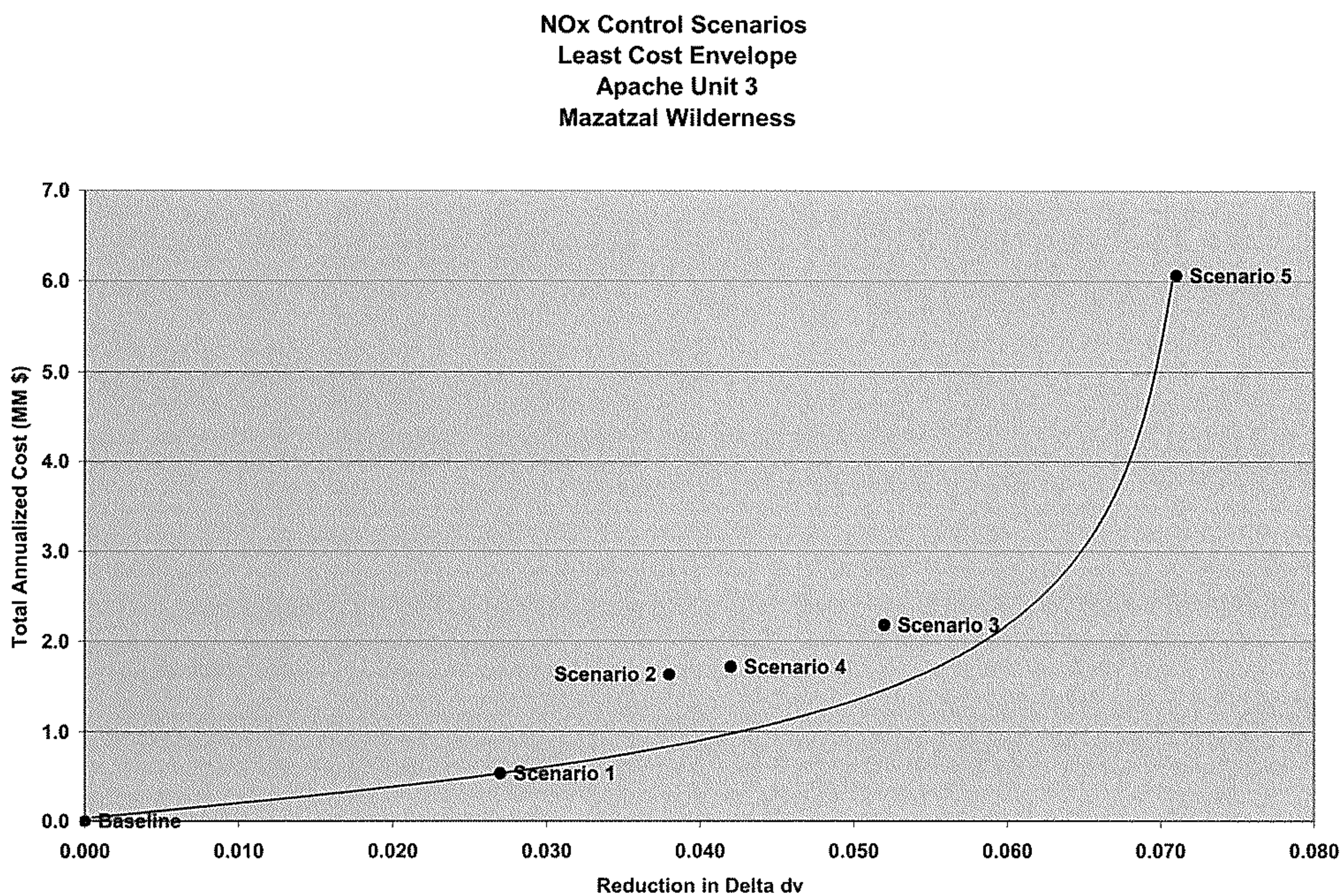

FIGURE C-14
NO_x Control Scenarios - Least Cost Envelope Pine Mountain Wilderness - Days Reduction
Apache 3

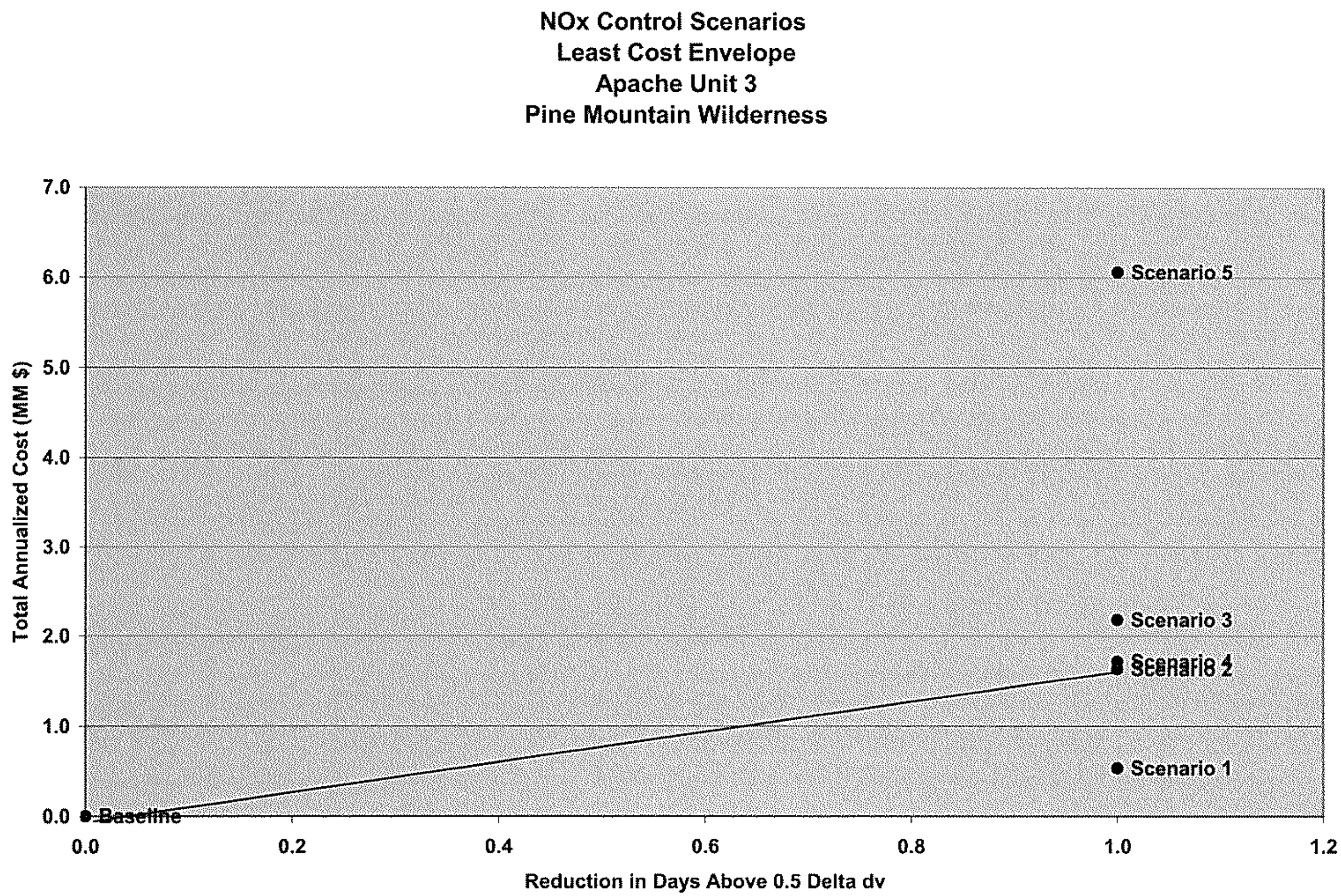

FIGURE C-15
NO_x Control Scenarios - Least Cost Envelope Pine Mountain Wilderness - 98th Percentile Reduction
Apache 3

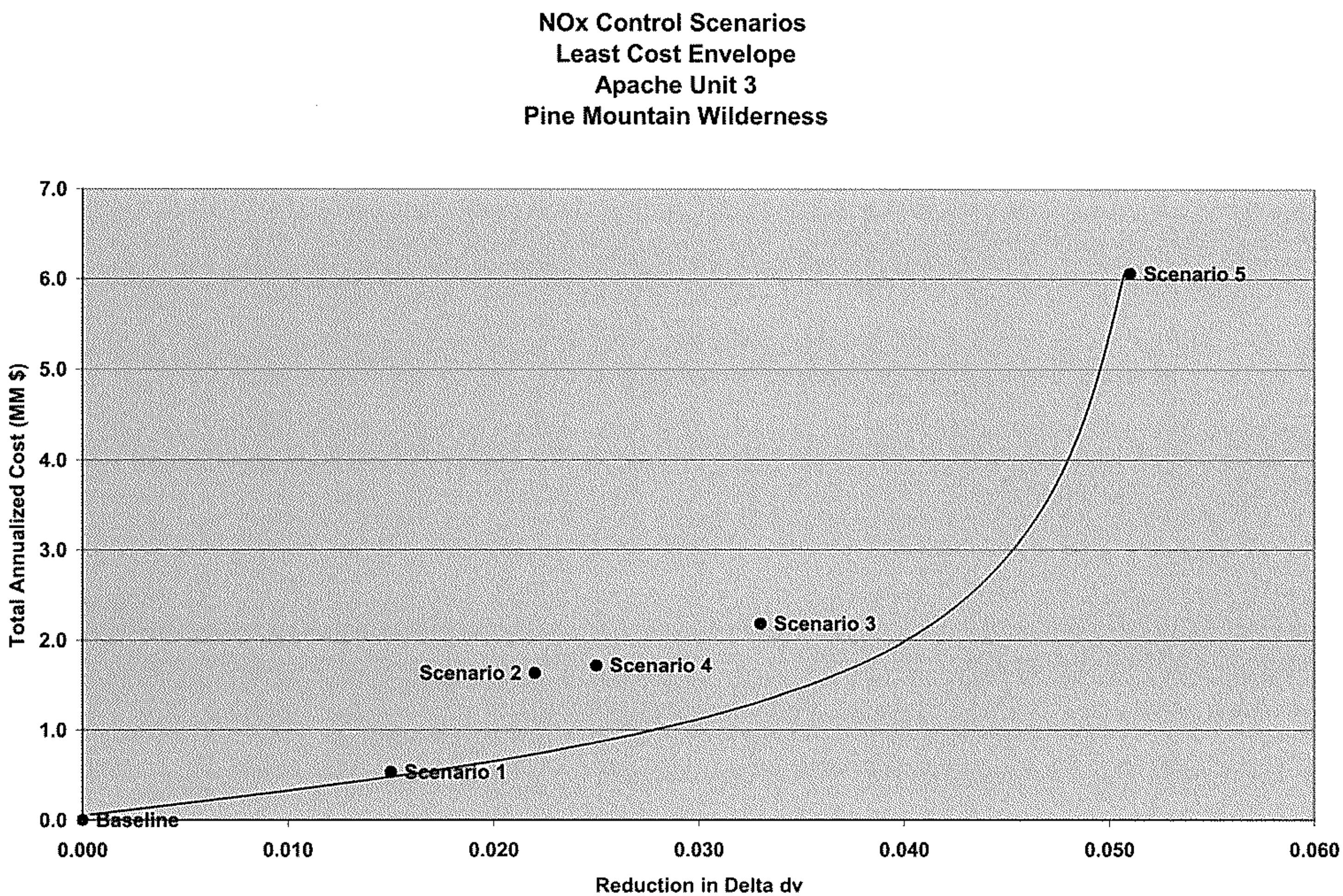

FIGURE C-16
PM & SO_2 Control Scenarios - Maximum Contributions to Visual Range Reduction at Gila Wilderness
Apache 3

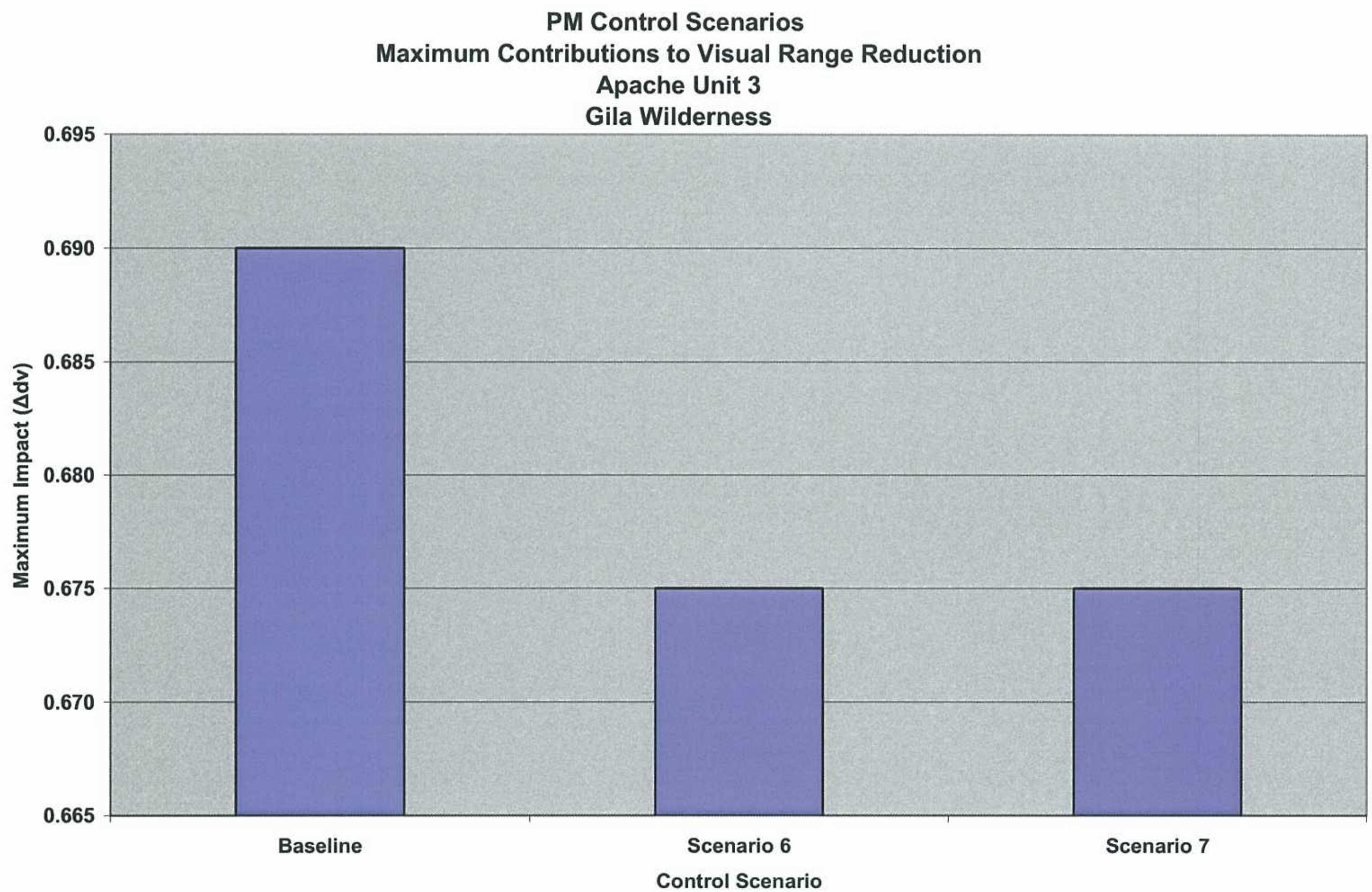

FIGURE C-17
PM & SO_2 Control Scenarios - Maximum Contributions to Visual Range Reduction at Mount Baldy Wilderness
Apache 3

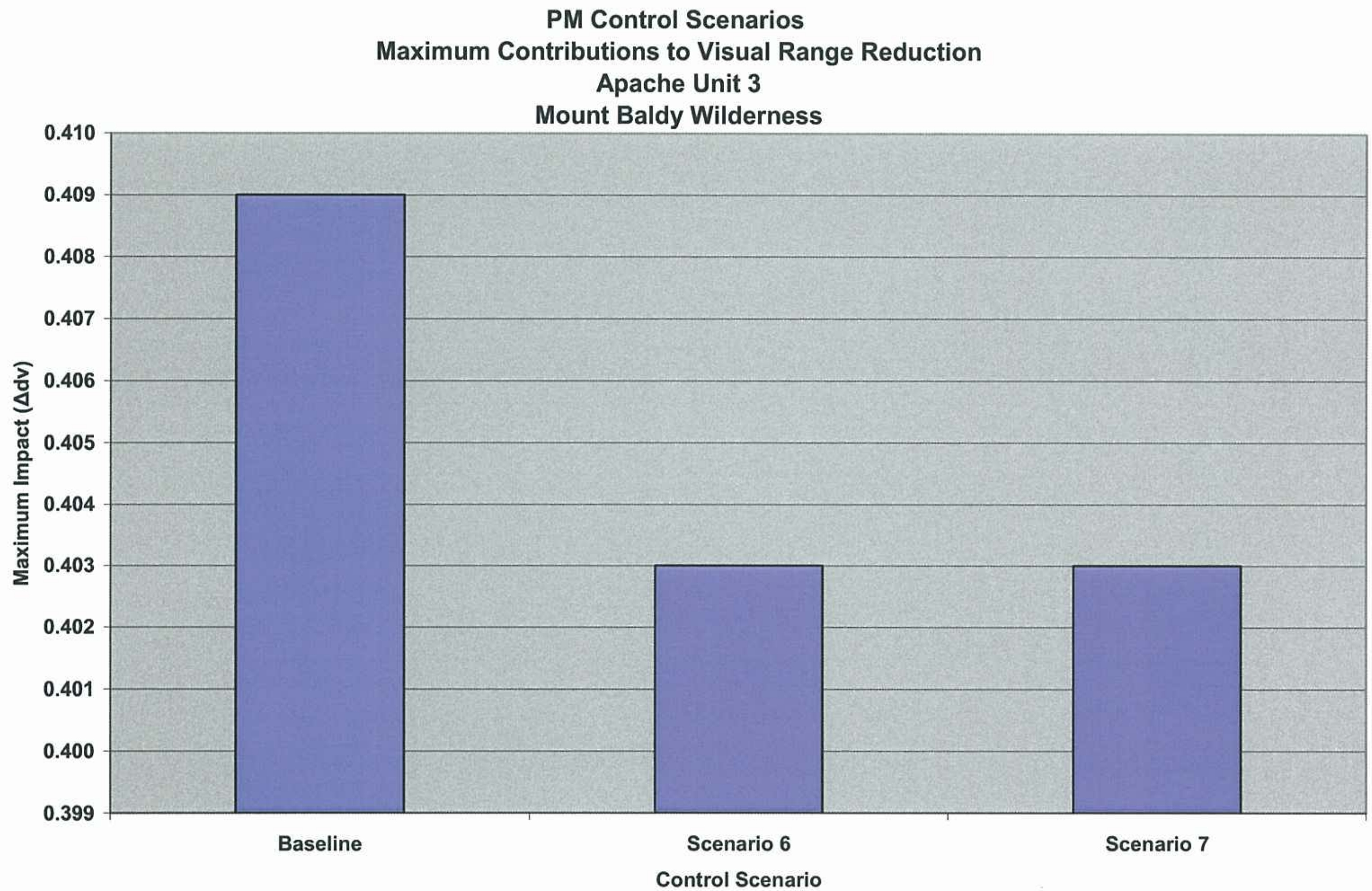

FIGURE C-18
PM & SO_2 Control Scenarios - Maximum Contributions to Visual Range Reduction at Sierra Ancha Wilderness
Apache 3

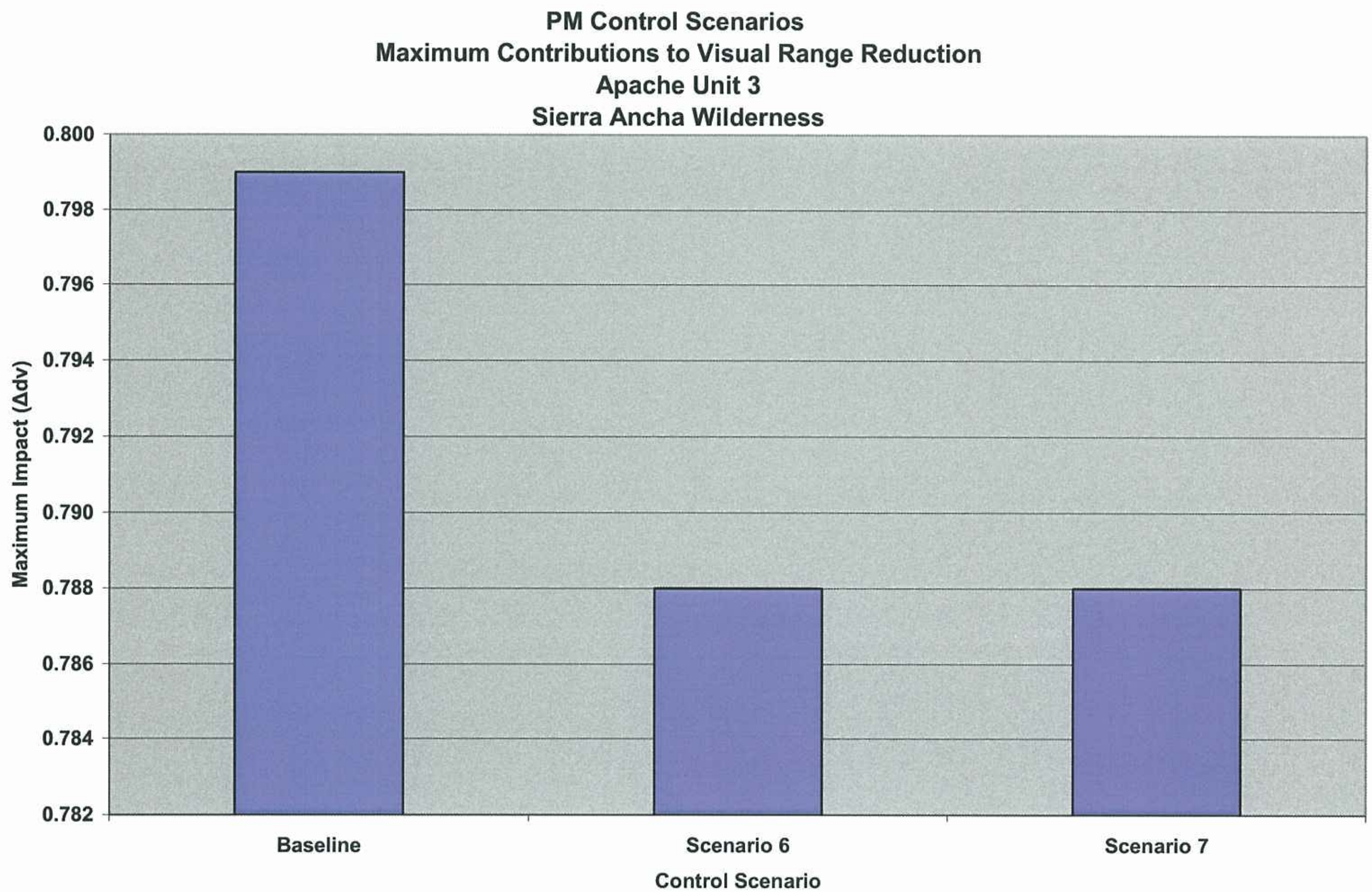

FIGURE C-19
PM & SO_2 Control Scenarios - Maximum Contributions to Visual Range Reduction at Mazatzal Wilderness
Apache 3

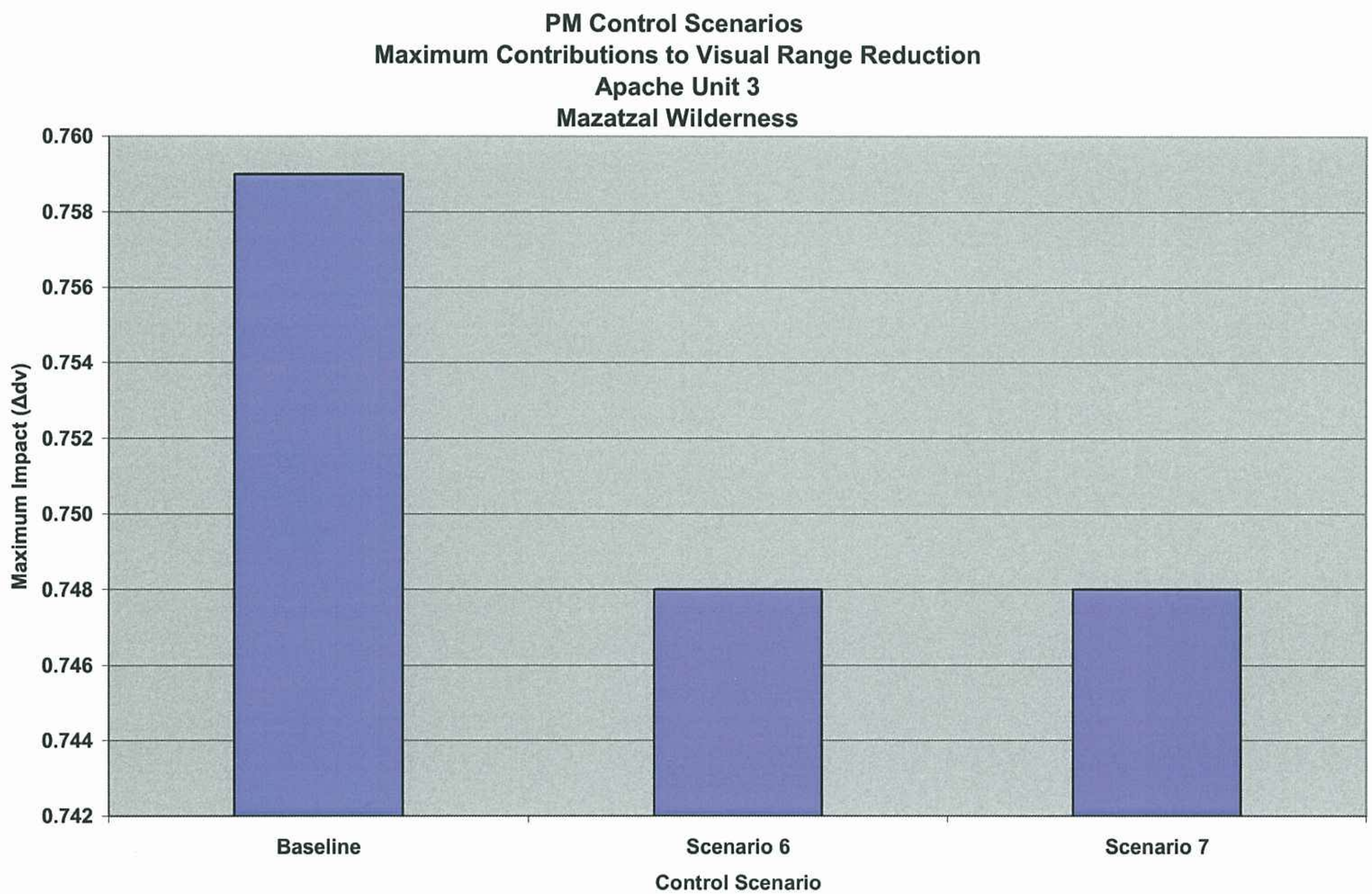

FIGURE C-20
PM & SO_2 Control Scenarios - Maximum Contributions to Visual Range Reduction at Pine Mountain Wilderness
Apache 3

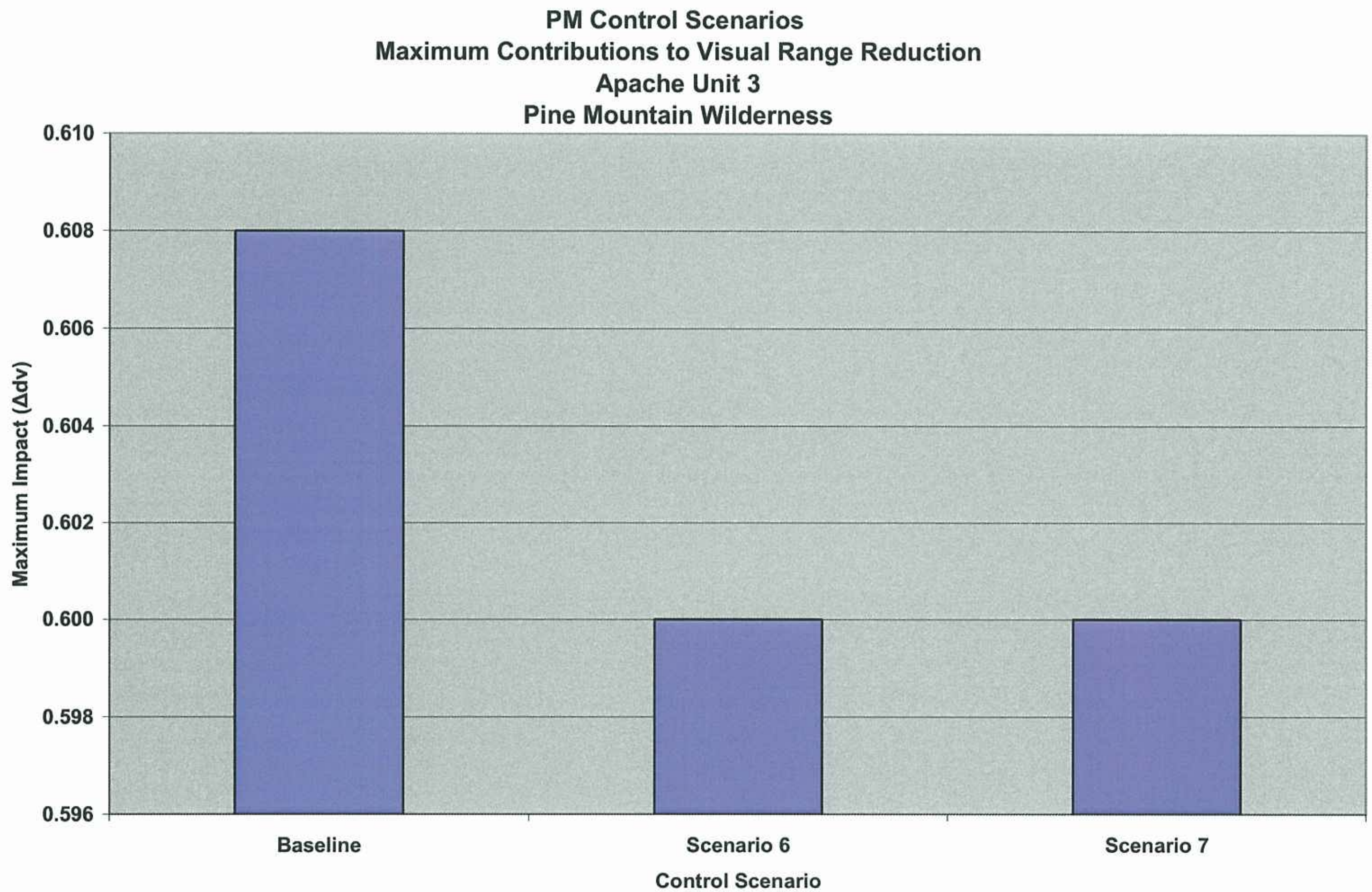

TABLE C-11
PM & SO_2 Control Scenario Results for Gila Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		2	0.000	0.000	0.000	0.000
6	Fabric Filter/SDA	2	0.010	2.192	NA	219.236
7	Fabric Filter	2	0.010	2.869	NA	286.859

TABLE C-12
PM & SO_2 Control Scenario Results for Mount Baldy Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		0	0.000	0.000	0.000	0.000
6	Fabric Filter/SDA	0	0.002	2.192	NA	1096.180
7	Fabric Filter	0	0.002	2.869	NA	1434.300

TABLE C-13
PM & SO_2 Control Scenario Results for Sierra Ancha Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		2	0.000	0.000	0.000	0.000
6	Fabric Filter/SDA	2	0.004	2.192	NA	548.090
7	Fabric Filter	2	0.004	2.869	NA	717.150

TABLE C-14
PM & SO_2 Control Scenario Results for Mazatzal Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		1	0.000	0.000	0.000	0.000
6	Fabric Filter/SDA	1	0.002	2.192	NA	1096.176
7	Fabric Filter	1	0.002	2.869	NA	1434.295

TABLE C-15
PM & SO_2 Control Scenario Results for Pine Mountain Wilderness
Apache 3

Scenario	Controls	Average Number of Days Above 0.5 ΔdV (Days)	98th Percentile ΔdV Reduction	Total Annualized Cost (Million$)	Cost per Reduction in No. of Days Above 0.5 ΔdV (Million$/Day Reduced)	Cost per ΔdV Reduction (Million$/dV Reduced)
Base		1	0.000	0.000	0.000	0.000
6	Fabric Filter/SDA	1	0.003	2.192	NA	730.784
7	Fabric Filter	1	0.003	2.869	NA	956.196

TABLE C-16
Gila Wilderness PM & SO_2 Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	0	0.010	2.192	NA	219.236

TABLE C-17
Mount Baldy Wilderness PM & SO_2 Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	0	0.002	2.192	NA	1096.180

TABLE C-18
Sierra Ancha Wilderness PM & SO_2 Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	0	0.004	2.192	NA	548.090

TABLE C-19
Mazatzal Wilderness PM & SO_2 Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	0	0.002	2.192	NA	1096.176

TABLE C-20
Pine Mountain Wilderness PM & SO_2 Control Scenario Incremental Analysis Data
Apache 3

Options Compared	Incremental Reduction in Days Above 0.5 ΔdV (Days)	Incremental ΔdV Reductions (dV)	Incremental Cost (Million$)	Incremental Cost Effectiveness (Million$/Days)	Incremental Cost Effectiveness (Million$/dV)
Scenario 6 vs. Baseline	0	0.003	2.192	NA	730.784

FIGURE C-21
PM & SO_2 Control Scenarios - Least Cost Envelope Gila Wilderness - Days Reduction
Apache 3

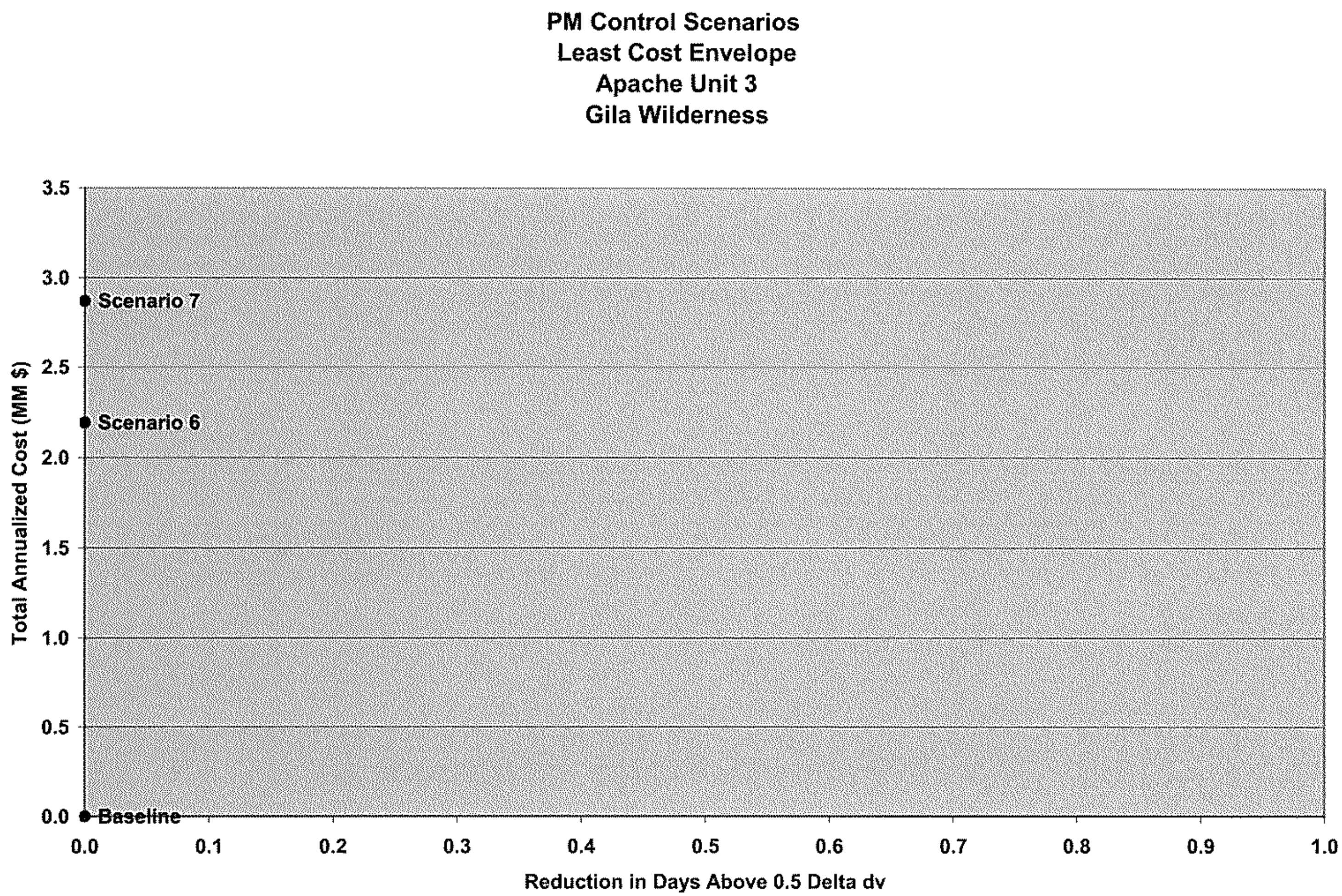

FIGURE C-22
PM & SO_2 Control Scenarios - Least Cost Envelope Gila Wilderness - 98th Percentile Reduction
Apache 3

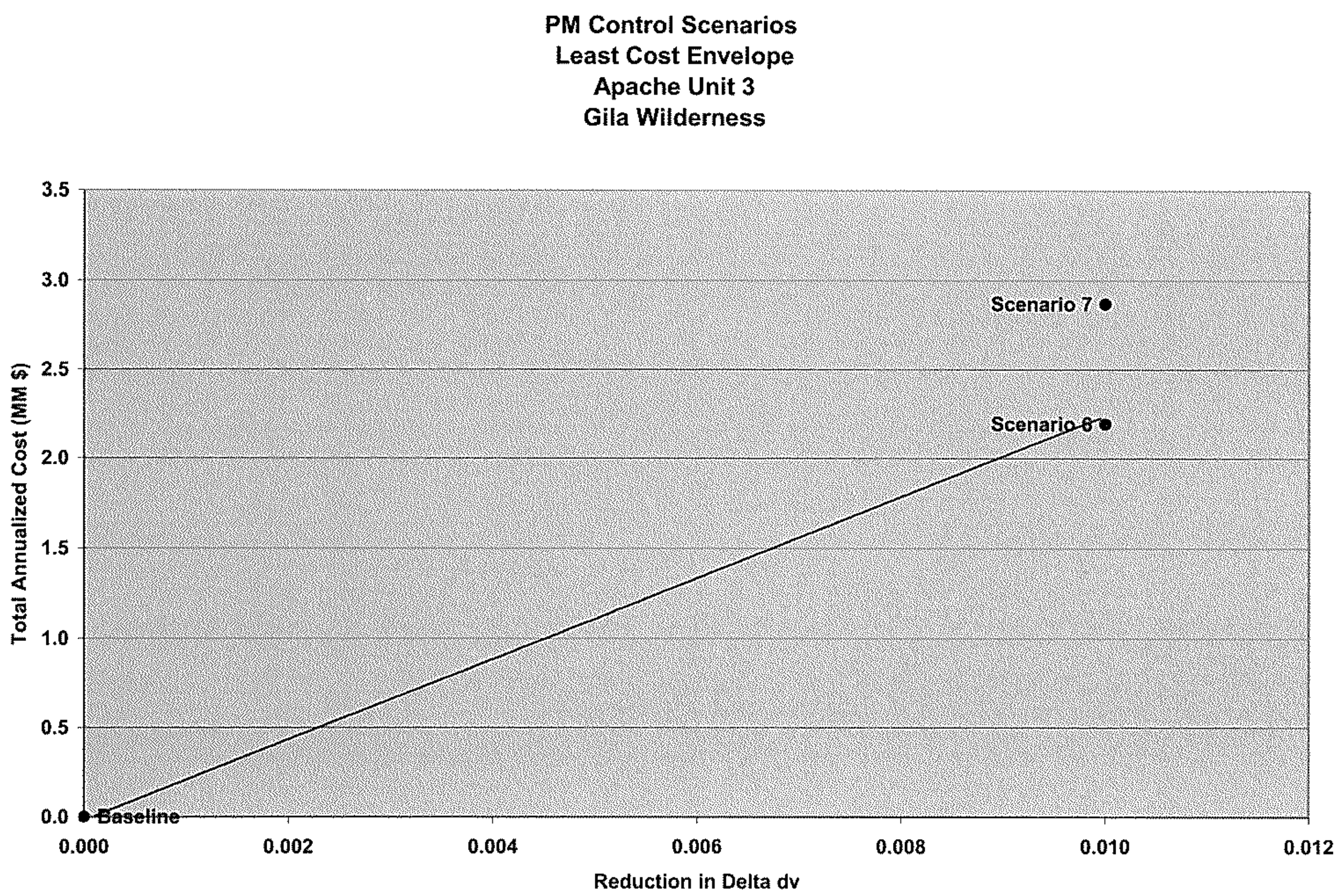

FIGURE C-23
PM & SO_2 Control Scenarios - Least Cost Envelope Mount Baldy Wilderness - Days Reduction
Apache 3

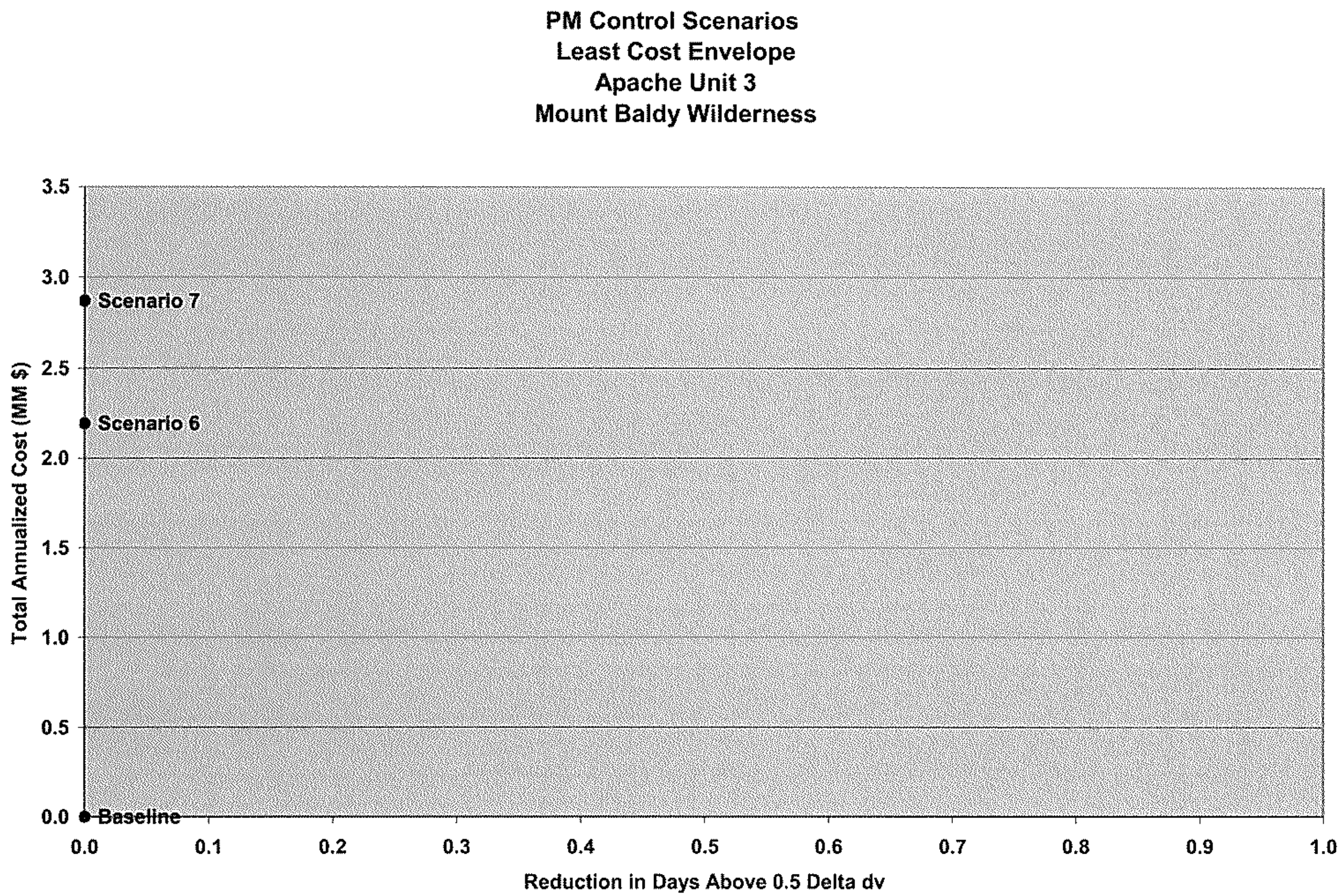

FIGURE C-24
PM & SO_2 Control Scenarios - Least Cost Envelope Mount Baldy Wilderness - 98th Percentile Reduction
Apache 3

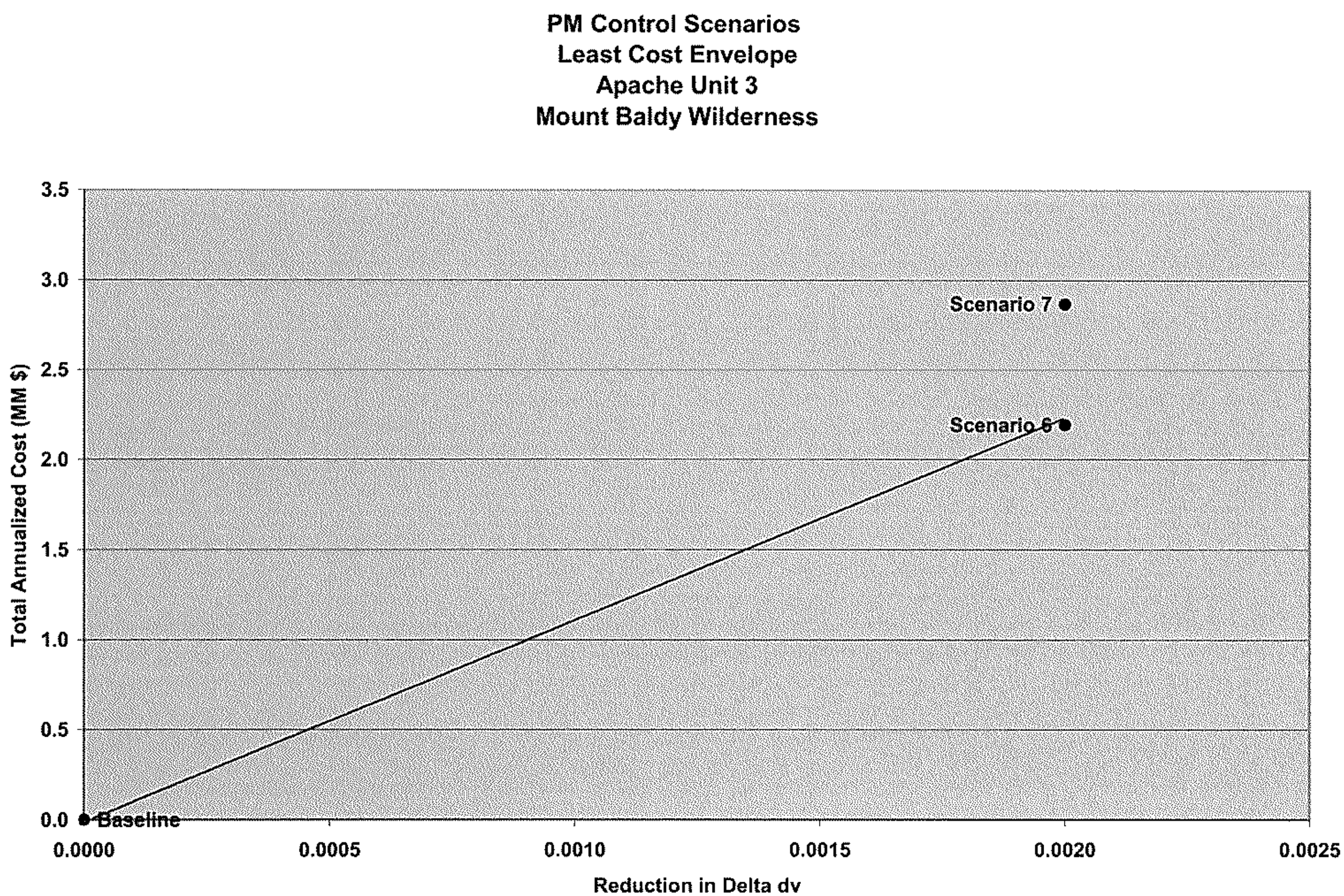

FIGURE C-25
PM & SO_2 Control Scenarios - Least Cost Envelope Sierra Ancha Wilderness - Days Reduction
Apache 3

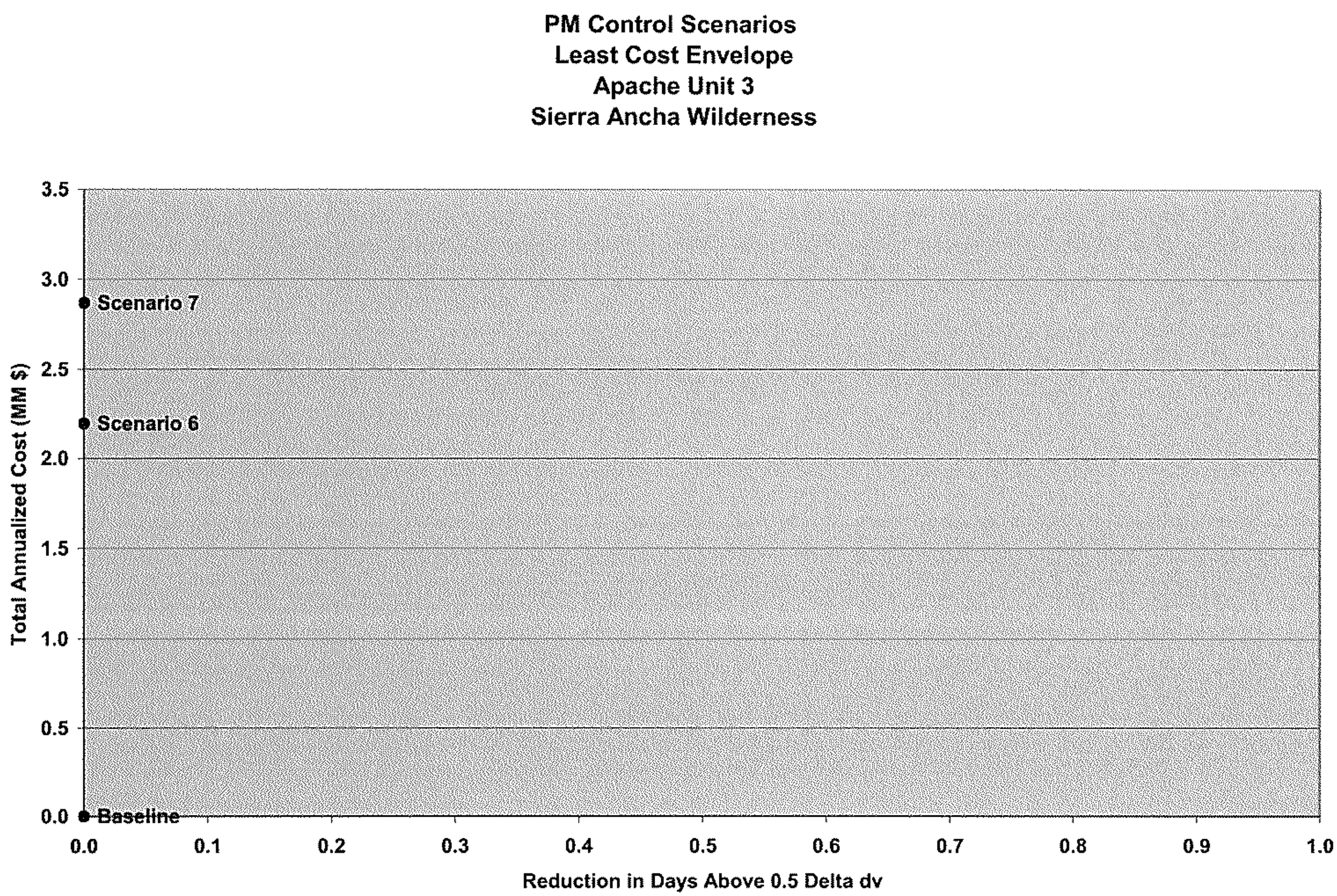

FIGURE C-26
PM & SO_2 Control Scenarios - Least Cost Envelope Sierra Ancha Wilderness - 98th Percentile Reduction
Apache 3

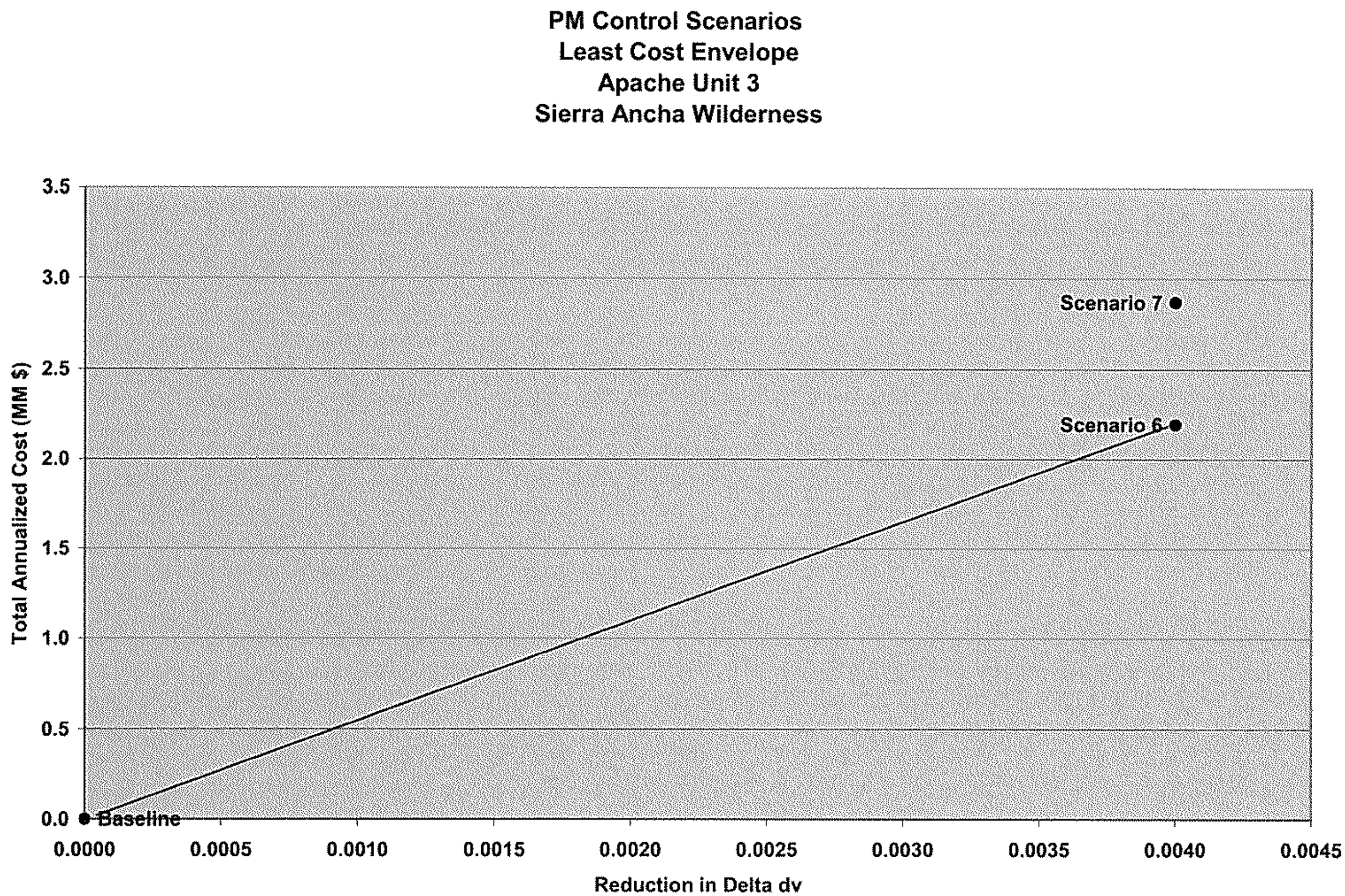

FIGURE C-27
PM & SO_2 Control Scenarios - Least Cost Envelope Mazatzal Wilderness - Days Reduction
Apache 3

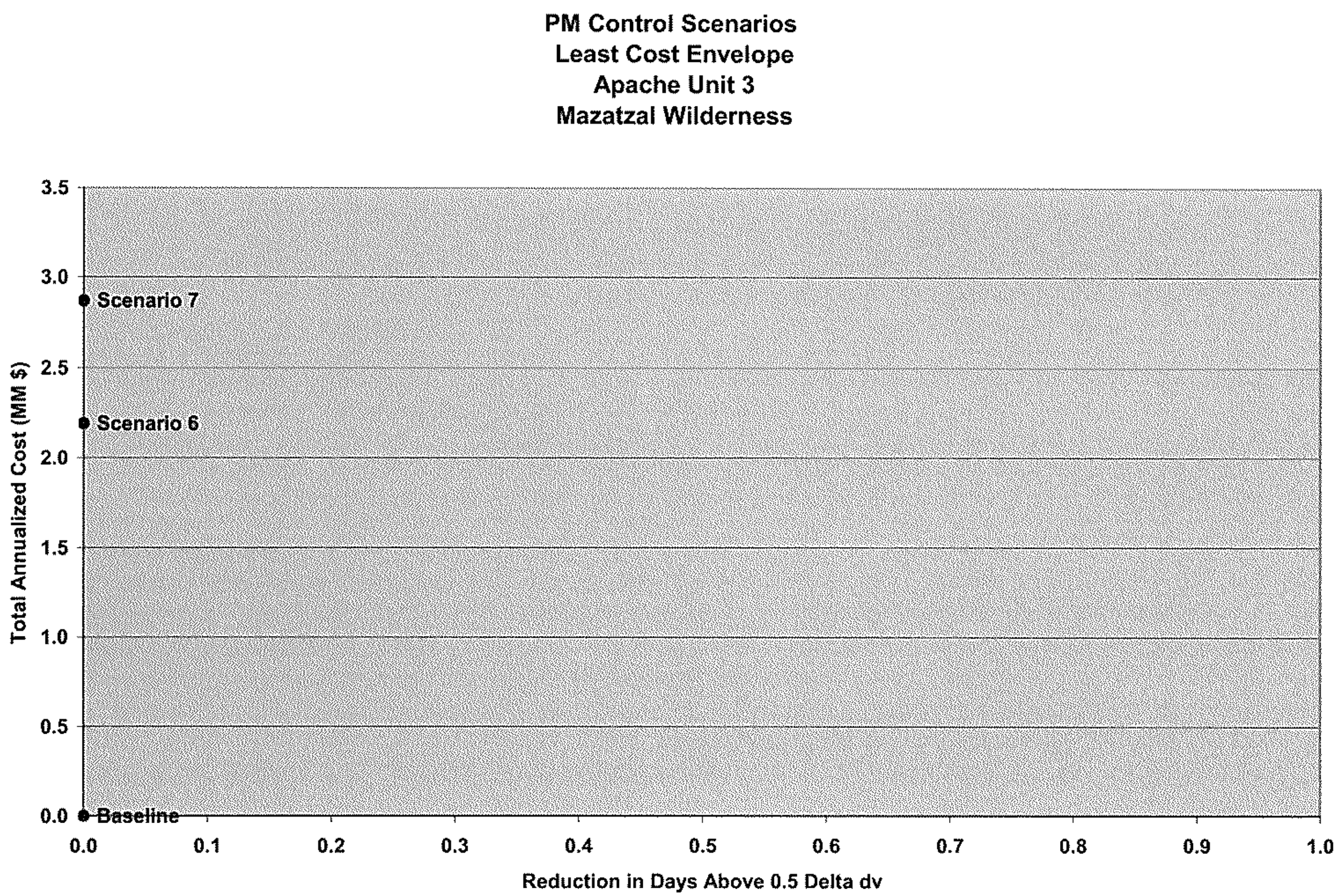

FIGURE C-28
PM & SO_2 Control Scenarios - Least Cost Envelope Mazatzal Wilderness - 98th Percentile Reduction
Apache 3

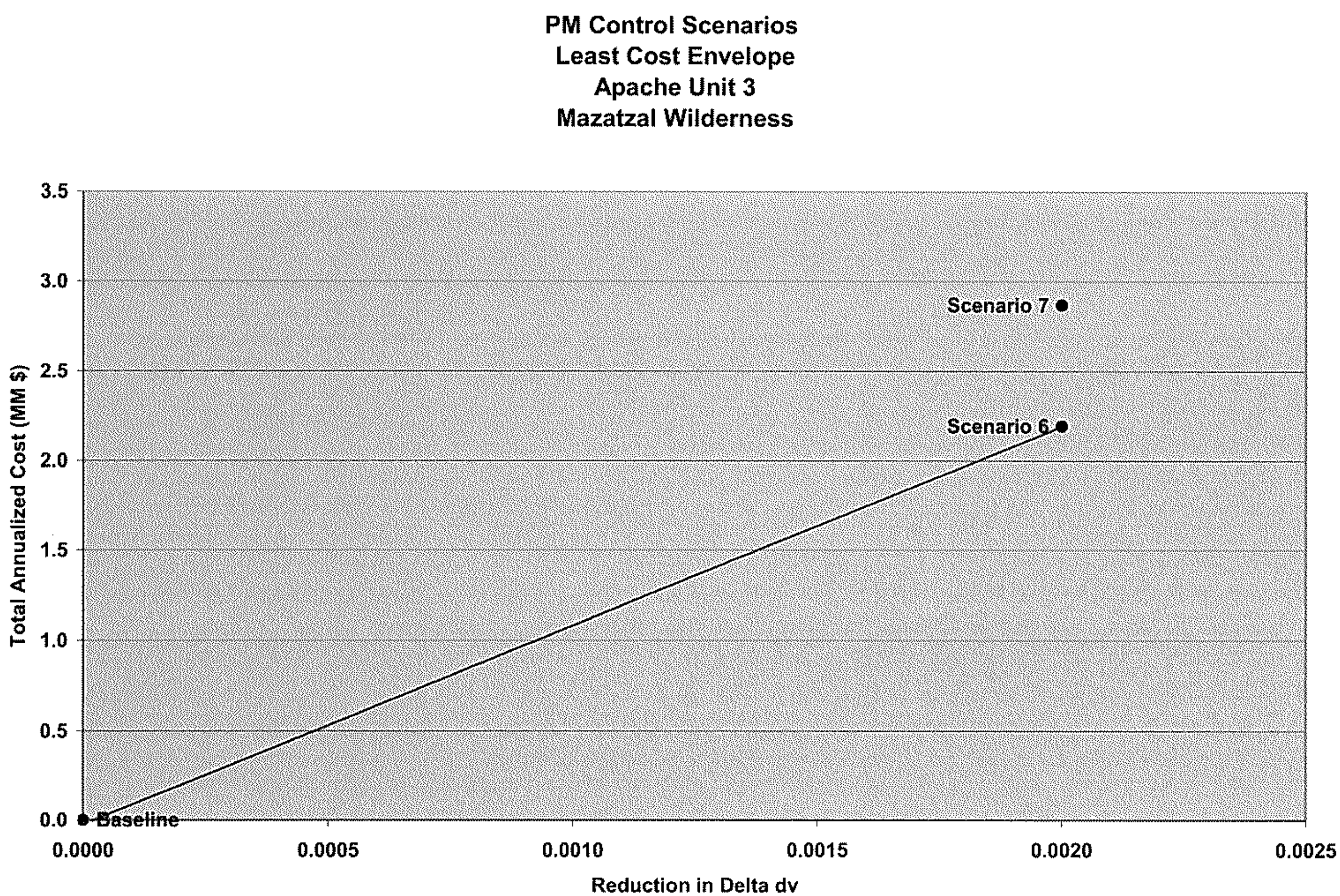

FIGURE C-29
PM & SO_2 Control Scenarios - Least Cost Envelope Pine Mountain Wilderness - Days Reduction
Apache 3

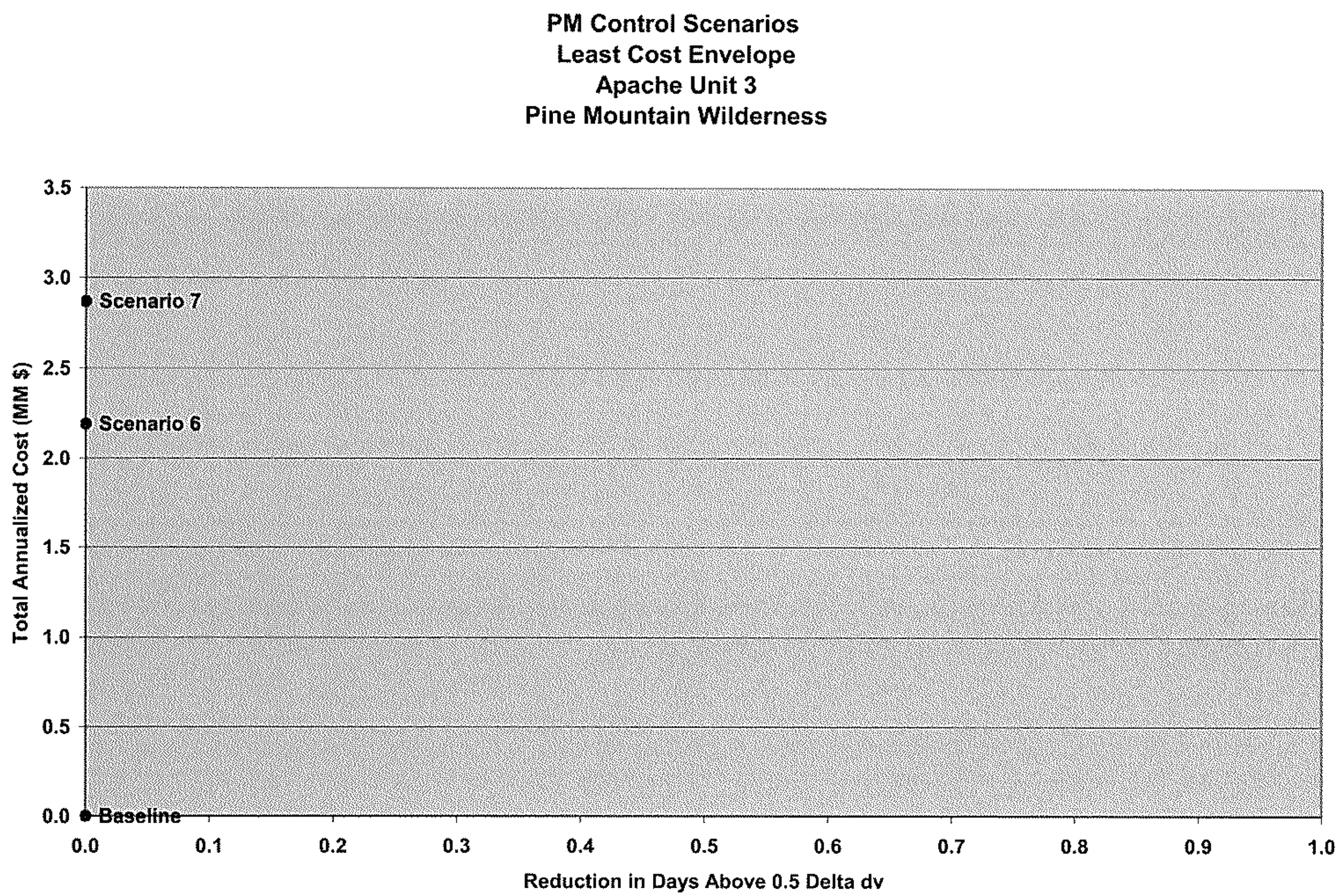

FIGURE C-30
PM & SO_2 Control Scenarios - Least Cost Envelope Pine Mountain Wilderness - 98th Percentile Reduction
Apache 3